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CHEMICAL & ENGINEERING NEWS

Real-time laser techniques
study transition states
Page 24

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NEWS

Volume 66, Number 45
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NOVEMBER 7, 1988

News of the Week

- **Japan's chemical industry targets global integration for next century, sees electronics and biotechnology as major growth areas.** Page 4
- **AAAS report finds Reagan Administration's R&D policies consistent over eight years, accomplishing most of what the Administration set out to do.** Page 5
- **BP Chemicals considers switch from naphtha to North Sea liquefied petroleum gas as ethylene source.** Page 5
- **Sigma Xi survey draws portrait of U.S. research scientists and their views on scientific and societal issues.** Page 6

Cover: Part of the femtosecond laser facility at California Institute of Technology. Photo courtesy of Jet Propulsion Laboratory

Letters 2

Concentrates

Business 7
Government 14
Science/Technology 17

The Department

Newscripts 68

Business

Many chemical companies are revising their compensation packages in effort to better motivate, as well as retain, experienced personnel. Page 8

Chemical industry should hold off making any concessions on tariffs at the GATT talks in Montreal next month, chemical trade adviser office recommends. Page 13

Government

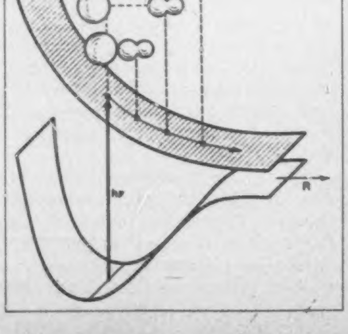
The second phase of California's toxic chemicals law, which governs toxics' discharge into drinking water supplies, went into effect last week. Page 15

Technology

Prospects for offshore mineral mining remain clouded by factors that include high startup costs, depressed metals markets, restrictive regulations, and turf disputes. Page 18

Awards

ACS award winners: Aczel, Anderson, Anson, Bartlett, Barton, Chandler, Chisholm, and Doering. Page 44



Special Report

Chemistry on the femtosecond time scale is addressing the chemical dynamics concerned with the very act of chemical transformation, the process of breaking one chemical bond and making another. Page 24

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LETTERS

Doctorate required

SIR: I do not believe that the errors about law degrees in my letter (C&EN, May 30, page 3) were of such gravity as to warrant K. Kay Shearin's comment, "The errors . . . should not be uncorrected" (C&EN, Sept. 5, page 3). My letter was in support of a proposal that a doctorate in chemical research be awarded to individuals who had made significant contributions in chemical research, but who had not earned a doctorate through the formal training that is designed to prepare them to conduct such research. The matter of law degrees was included merely to show that the requirements for a doctorate are not immutable; that the doctorate is now awarded to law graduates for the same academic training that until recently yielded only a bachelor's degree. If I had used the correct term "Bachelor of Laws" rather than "Bachelor of Laws and Letters" for the LL.B. degree, the sense of my intended message would in no way have been affected.

Shearin strongly disagrees with my opinion that those who have doctorates are widely looked upon as being at the top of their professions. Would that this were so; there would then be no need to advocate the introduction of the degree proposed by Altamura and others. But one need only look at the advertisements in C&EN for support of my opinion. Among the employment ads for nonacademic positions in the May 5 issue, 14 required a doctorate; none of these offered to waive this in exchange for accomplishments.

Joseph Levine
Emeritus Member
Silver Spring, Md.

New educational paradigm

SIR: David Wagger, in his letter (C&EN, Aug. 22, page 3) suggests that "in order to provide the instructors to teach our future citizens, today's scientific community, of which ACS is a part, must provide from its membership persons who will devote time, effort, and expertise in developing a new educational paradigm in which science and mathematics are stressed appropriately." I believe this is true but that the chemical community may not yet be ready to address these issues.

At this time Purdue has the only division of chemical education within a chemistry department in the U.S. I think the division is trying to provide the types of people that Wagger suggests are needed. There are essentially three types of students in the program. First, there are those who wish to become certified to teach high school. The second consists of those who want to teach chemistry at a small, liberal arts college. Students in the third group are also interested in teaching, but in addition they are interested in researching how students learn (or don't learn) chemistry and trying to improve our teaching practices through this research. Although each group has different interests, as a whole they are attempting to "devote time, effort, and expertise in developing a new educational paradigm."

Each of these three groups works toward a master's degree in chemistry. Those seeking certification generally pursue a nonthesis program consisting of graduate courses in chemistry and education. The two groups interested in careers at the college level take courses in chemistry and education, and work on a thesis project looking at some aspect of how students learn chemistry or how it can be better taught. After completing the master's program, these two groups switch into the education department to work toward a doctorate in science education.

One problem with this approach is that the people completing a doctorate in science education are not accepted as part of today's scientific community in the same way as someone who is completing a doctorate in chemistry. Because they choose to research problems that are nonchemical in nature they are not viewed as equals. Although this may sound like an ideological problem, it translates in the real world into terms of what sorts of positions these graduates obtain.

Out of the four most recently graduated students from this program, two are in tenure-track positions in education departments, and the other two are in nontenure track, temporary teaching positions in chemistry departments. Those chemistry departments seeking chemical educators almost invariably desire candidates with a doctorate in chemistry. I think the people completing the program in science education have greater expertise for developing a new educational paradigm than people completing a program in chemistry. However, those chemistry departments seeking candidates for a position in chemical education would rather hire someone from their own scientific community.

I am trying to circumvent this problem. After completing my master's thesis investigating graduate student problem solving in organic synthesis and watching several of the older graduate students in the chemical education divigame," and therefore asked the Japanese the same types of questions Dow executives were asked. He says the delegation did a little hedging of their own in divulging their goals and strategies.

"I don't think this was an expedition to look for joint ventures," Snyder says. "Rather, it was an effort to explore the American and European chemical industries, determine what our priorities are, how we carry out our work, how we look at Japan. The one thing I learned is how far downstream they seem to be interested in. I don't think the typical chemical manufacturer sees himself as diving toward activities like manufacturing for the auto industry as they seem to indicate."

Wil Lepkowski

R&D policy of Reagan Administration examined

With voters going to the polls to choose a new President this week, the American Association for the Advancement of Science thought it a good time to examine how research and development has fared during President Reagan's two terms. The assessment comes in a pamphlet-sized publication entitled "R&D in the 1980s: A Special Report."

The report finds the Reagan Administration's R&D policies to "have been remarkably consistent" over the eight years it has been in power. It has emphasized heavy investment in military R&D, provided substantial increase to nondefense basic research, resisted increases in biomedical research, and proposed reductions in applied research in civilian agencies.

Between fiscal 1980 and fiscal 1988, total federal R&D spending increased an estimated 86% to about $59 billion. Even after adjusting for inflation, this represents an overall constant-dollar increase of 26%, the report says. Leading the way, quite expectedly, is the Defense Department. At the start of the decade, DOD spent about $14 billion on R&D; by fiscal 1988 it was spending over $38 billion. DOD's budget for just one area, tactical R&D, the report notes, is about twice the size of the National Institutes of Health's entire research program.

The National Science Foundation, whose budget the Administration initially wanted to pare back and restructure, according to the report, has benefited from the Administration decision in 1984 that basic research was essential to the nation's economic competitiveness. Thus, after falling in the early part of the decade, the report says NSF's budget rebounded, ultimately rising 74% from 1980 through 1988, or 17% in constant-dollar terms. However, not all of that increase went into basic research because of Congress' emphasis on science and engineering education programs.

NIH, on the other hand, experienced erratic growth during the Reagan years, the report says, noting that Reagan's proposed budgets for NIH never compensated for inflation, and often proposed spending less than was appropriated in the preceding years. It is only because of a beneficent Congress that NIH's budget has doubled since 1980, rising 34% in real terms from 1980 to 1988. The report notes, however, that almost 57% of NIH's cumulative new spending in that period went to AIDS research.

Overall, except for its attitudinal turnaround on NSF, it is apparent from the report that the Administration accomplished most of what it set out to do.

Janice Long

Reagan Administration has been good to basic research

$ Billions	1988[a]	1980[b]	% change $ Current	% change $ Constant
Defense R&D[c]	$40.2	$15.0	168%	83%
Development	36.7	12.5	194	99
Applied research	2.6	1.9	38	−7
Basic research	0.9	0.6	50	11
Civilian R&D	18.8	16.7	13	−24
Basic research	8.6	4.2	107	40
Applied research	6.5	5.0	29	−13
Development	3.7	7.5	−50	−66
TOTAL	$59.0	$31.7	86%	26%

a Estimate. b Actual. c Includes Department of Energy defense R&D. Source: American Association for the Advancement of Science

BP Chemicals targets LPG as ethylene source

BP Chemicals is looking to tap North Sea liquefied petroleum gas (LPG) as an ethylene source to replace currently used naphtha. If that happens, an existing cracker at Grangemouth, Scotland, will be modified to use LPG, boosting annual ethylene output there some 250,000 metric tons in four or five years. It will mark the first usage of LPG in the U.K. to make lower olefins.

According to John N. Turnbull, who is responsible for petrochemicals and polymers at BP Chemicals, the policy is to run the company's crackers at full capacity, and meet remaining ethylene needs with purchases on the open market. Most of the ethylene goes to make polyethylene, one of BP Chemicals' major business areas.

"This remains our policy," he says. "But looking ahead, we foresee our ethylene deficit rising to a quarter of a million tons a year. We can't see filling that level of deficit through purchases." He rules out the option of building a new cracker as uneconomic. But he sees a case for adapting and extending one that's already in place.

By 1992, if the planned expansion were not made, BP Chemicals would have capacity for making 270,000 metric tons of ethylene at Grangemouth, and 330,000 metric tons at Baglan Bay in Wales. A further 150,000 metric tons is available from a cracker shared with ICI, bringing the total to 750,000 metric tons. Its U.K. ethylene needs in that year will reach 760,000 metric tons. Add to that the 240,000 metric tons required to make polyethylene at Antwerp, Belgium, and the ethylene deficit reaches 250,000 metric tons. "It's clear that we can't sustain our present level of ethylene purchases without sacrificing our strong strategic base in the product," Turnbull points out.

Currently, more than half the U.K.'s yearly polyethylene requirements are met by imports, he notes. "It makes economic sense to upgrade LPG rather than export it and bring back the polymer," he reasons. Moreover, he adds, Grangemouth is an ideally suited location to take deliveries of the increasing quantities of LPG arriving from North Sea operations.

And there still is plenty of growth ahead for polyethylene. This year's 7.5 million metric ton demand in Western Europe compares with 5.7 million metric tons five years ago. In 1993, Turnbull projects usage exceeding 9 million metric tons, increasing to more than 11 million metric tons by the turn of the century.

Dermot O'Sullivan

Poll draws portrait of U.S. scientists' views

A rare portrait of U.S. research scientists and their views on scientific and societal issues, including political questions, is drawn in a survey released late last month by Sigma Xi, the scientific honor society, at its annual meeting in Orlando, Fla.

Among the findings:

- U.S. scientists disagree with the nation's science funding and management policies in such key areas as peer review, politically targeted research funding, and support for "Big Science" projects.
- They find their scientific careers fulfilling, have high regard for science and its values, and recommend science as a career.
- They mirror the U.S. public's social and political views.
- Their postcareer and retirement issues are increasingly important.

The survey grew out of Sigma Xi's effort this year to enhance public understanding of science and technology, and builds on its successful 1986 survey. Its aim was to collect information that would improve understanding of scientists by a public that often stereotypes the scientist as a remote and forbidding Dr. Strangelove, notes project director Jack Sommer, the society's chairman of international programs.

The 80-item questionnaire was mailed Aug. 11 to a sample of about 10,000 of the society's 115,000 members. The results reflect 3332 responses received by Sept. 15. Sommer says the sample is representative of Sigma Xi's membership. The sample does not fully represent all scientists and engineers. However, he notes, "no other survey can claim such a comprehensive canvas." The survey canvassed scientists and engineers in more than 160 disciplines from academia, industry, and government.

It shows that scientists are anchored in the U.S. mainstream, he adds. Half participate in religious activities regularly. Majorities oppose decriminalization of narcotics and accept capital punishment as legitimate. The scientists divide evenly between liberal and conservative in political views.

Lack of public understanding of science is the most important issue now facing science, say 40% of the respondents, followed by overpoliticization of research (24%) and interruptions in research funding (21%). Of those with an opinion, 81% say Congress should not target research projects for federal funding, and research funds are "tied too closely to prevailing political priorities and fashions." Congressional "pork barrel" allocations of research funds are condemned by 88% of those taking a position.

Scientists give low priority to funding Big Science

Research area	% support[a]
Untargeted individual research awards	23%
Biosphere/geosphere systems	19
AIDS (acquired immune deficiency syndrome)	16
Engineering Research Centers and Science & Technology Centers	13
Superconducting materials	9
Space station	6
Strategic Defense Initiative	4
Human genome project	4
Superconducting Super Collider	2
Other[b]	4

a Surveyed scientists were asked to choose the "three best uses of public funds for scientific research" at this time, and results were normalized to total 100%. b Includes substantial support (48%) for health-related research areas. Source: Sigma Xi survey

Moreover, 64% of those with an opinion launch what Sommer calls "a startlingly intense indictment" of the peer review process for awarding research grants; 32% believe "reviews are marred by cronyism, old boy networks, and insider politics." And 27% say "original, nonmainstream ideas are unlikely to be funded." Fewer than 8% say "peer review works well as it is."

Survey respondents agree with the call of National Academy of Sciences president Frank Press for scientists to set research priorities themselves, so as to present a more coherent appeal for funding to Congress and the public (C&EN, May 2, page 8). When asked to choose research areas for support, participants give top priority (23%) to untargeted individual research awards. Next are biosphere/geosphere systems (19%)—reflecting environmental concern—and acquired immune deficiency syndrome (AIDS) (16%). After that come the Engineering Research Centers and the Science & Technology Centers (13%), and superconducting materials (9%). Ranked lowest are four major national programs: the space station, Strategic Defense Initiative, human genome project, and Superconducting Super Collider. Thus, Sigma Xi members agree with Press in giving highest priority to basic scientific research, training, and education, and to national crises like AIDS, and in assigning lowest priority to "political projects" like the space station and defense R&D.

The survey, "Sketches of the American Scientist," is available for $3.00 from Sigma Xi, 345 Whitney Ave., New Haven, Conn. 06511.

Richard Seltzer

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Preserving the Past

Chemistry helps conserve museum objects Page 10

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CHEMICAL & ENGINEERING
NEWS
NOVEMBER 14, 1988

News of the Week

- **Quantum chemist William A. Goddard III is under attack for a theory of high-temperature superconductivity being developed by his group.** Page 6
- **Just one week after closing down its rayon manufacturing facility, in Front Royal, Va., Avtex Fibers has restored the plant to full operation.** Page 7
- **Texas has been selected as the site for the Superconducting Super Collider.** Page 7
- **President-elect George Bush says he intends to raise the status of science adviser to Assistant to the President.** Page 7
- **Computer virus attack on research network sparks consideration of added measures needed to prevent future incursions.** Page 8
- **Du Pont has proposed a joint venture to commercialize high-tech food products.** Page 8

Cover: Stern of 17th century Swedish ship *Wasa* at museum in Stockholm. Photo by Curtiss E. Peterson

Letters 4

Concentrates
Business 21
Government 41
Science/Technology 44

The Departments
New Products 51
Software/Database Update 57
ACS Comment 63
ACS News 64
Meetings 69
Newscripts 86

Business

Banner performance of major U.S. chemical companies continued into the third quarter, with earnings soaring 65%; Henkel has realigned its metal treatment business to gain edge in global market; Ireland anticipates major benefits from 1992 European Community plan to eliminate trade barriers. **Page 24**

Government

Many universities are putting off repairs of research facilities because of problems in obtaining funding for renovation, NSF survey finds; Biotechnology Institute may be formed to provide technical and legal training for biotech patent examiners. **Page 42**

Science

Chemistry of cubane enters new era, with development of procedures that have opened the way for synthesis of new cubane derivatives; oligonucleotide probe that cleaves phage DNA site-specifically holds promise for genome mapping; CHEMRAWN II is still at work, six years after it convened. **Page 45**

Books

"Stones in a Glass House" and "Saving Our Skins" delve into the threat of chlorofluorocarbons to Earth's atmosphere. **Page 59**

Awards

ACS award winners: Enke, Henis, Hubbard, Kanigel, Kirchner, Bowers, Klibanov, Knight, and Knowles. **Page 65**

News Focus

Chemical methods are helping scientists to restore and conserve important historical and archeological relics. **Page 10**

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LETTERS

Contributions of chemists

SIR: The report of Geoffrey Cantor's comments regarding British Prime Minister Margaret Thatcher's selection of Michael Faraday as her historical hero is an interesting observation (C&EN, Aug. 22, page 92).

It should be noted, however, that it is to Thatcher's credit that she did not let the political views of Faraday overshadow her great appreciation of his remarkable contributions to both chemistry and physics.

It is encouraging to note that although as Prime Minister she has turned her major attention to public affairs, she is not unaware of the importance of scientists in history.

In this connection the Beckman Center for the History of Chemistry is to be congratulated on bringing to public attention the past contributions of chemists. Unfortunately, entirely too many chemists know very little about the work of those who have made the science of chemistry what it is today.

William J. Burke
Tempe, Ariz.

Interest in secretariats

SIR: The ACS Focus on divisions (C&EN, Aug. 29, page 40) ignored several facts that bear on the role and the vitality of divisions in ACS as follows:

- In addition to 32 divisions, there are 11 subdivisions or one third again as many additional area-focused programing entities in ACS, for a total of 43. Presumably more are yet to come.
- In apposition to that fragmentation there exist several secretariats that serve as "lintels across the columns." The first such was the Macromolecular Secretariat, formed many years ago, followed by the Computer Secretariat in the late 1970s. Recently there has been a spate of secretariats: biotechnology several years ago, catalysis just recently, and now we have a movement afoot to create a Material Chemistry Secretariat. Secretariats are not explicitly called out anywhere in the ACS constitution or bylaws, but are formed under a variety of agreements—even just oral—among participating divisions.
- There is a Divisional Officers Caucus—another ad-hoc organization with no explicit mention in the ACS constitution or bylaws—that complements the Committee on Divisional Activities, which is a legally constituted part of ACS governance.

As the person who took the initiative to form the Division of Computers in Chemistry in 1974, I found that the mechanism for so doing was well defined and the pathway for carrying the petition through the process clearly marked.

As the person who has taken the initiative to promote a Materials Chemistry Secretariat, I have found a lack of understanding among the rank and file—and even among volunteer officers and staff—about just what a secretariat is and how it functions.

Our MCS steering committee has found there are many persons active in materials chemistry research who are enthusiastic about the concept of an ACS focus on materials chemistry and who see that transcending the interests of any single division. What is difficult to explain to them is why a bridging function such as a secretariat is constrained to an ad-hoc and ill-defined existence in ACS.

Given the increasing interest in secretariats—and the already large number of divisions and subdivisions in ACS—it seems to me we would be well advised to study the secretariat phenomenon and to consider whether or not the time has come to accord them full partnership in ACS.

Peter Lykos
Illinois Institute of Technology
Chicago

Trees getting even

SIR: Congratulations to the editor who did such a magnificent job of positioning the two articles on trees on opposing pages in your Sept. 19 issue—"Air pollution's damage to trees, crops detailed" on page 20, and "Trees contribute significantly to urban smog," page 21.

Clearly, the moral to be drawn is that the trees are trying to get even!

Jim Verdieck
Thousand Oaks, Calif.

Business and higher education

SIR: The comments of Arnold Weber (C&EN, Aug. 29, page 3) about the role of business in strengthening higher education are important and timely. Weber quite rightly addresses the need for scientists and nonscientists to be mutually and effectively educated in each others' broad areas. He notes in passing that business "should be as interested in the education of the English or economics major. . .as it is in the engineer."

This point cannot be overstated and indeed needs to be taken further. Although there is no question that the increasingly acute projected shortage of scientists and engineers in the U.S.—particularly among ethnic minorities—must be addressed in a meaningful way,

Chemical Earnings Continue Strong Gains in Third Quarter

William J. Storck,
C&EN Northeast News Bureau

Sometimes it seems that the economic recovery is just going to go on forever. And looking at another stellar performance in chemical earnings in the third quarter does nothing to make that feeling go away.

Once again, U.S. chemical companies turned in a banner performance for the period, with earnings rising about 65% from last year's third quarter. The strong earnings performance in chemicals also helped results for major oil and diversified companies that produce chemicals.

The only worrisome aspect is that some specialty companies that rely on commodity chemicals for feedstock are feeling a cost-price squeeze. For instance, Witco chairman William Wishnick states that, although the company was pleased with its record results, there had been a noticeable trend in the third quarter of continuing increased costs of raw materials, and only part of those increased costs had been passed on to customers. Witco's quarterly earnings increased 13% to $20 million on a sales rise of 9% to $403 million. Wishnick says the company will pass along the increased costs as market conditions warrant.

However, in the main, the story is getting to be a very familiar one. Strong demand, both domestic and export, for chemical products is causing tight supplies and therefore high capacity use. This is an ideal situation for rapidly rising earnings. The shortness of some chemical products allows for price increases that

Chemical industry leaders for the third quarter . . .

Sales

Rank 1988		$ Millions	Rank 1987
1	Dow Chemical	$4150.0	1
2	Union Carbide	2108.0	3
3	Monsanto	2022.0	2
4	W. R. Grace	1390.4	4
5	American Cyanamid	1094.1	5
6	Quantum Chemical	812.4	7
7	Arco Chemical	696.0	11
8	Hercules	686.9	6
9	B. F. Goodrich	640.4	10
10	Air Products	622.0	8

Earnings

	$ Millions	Rank 1987
Dow Chemical	$632.0	1
Union Carbide	213.0	3
Arco Chemical	126.0	4
Monsanto	116.0	2
Quantum Chemical	99.8	13
B. F. Goodrich	68.8	11
American Cyanamid	64.1	5
Ethyl	62.2	7
Georgia Gulf	53.1	12
W. R. Grace	50.6	8

Profitability

	Earnings as % of sales	Rank 1987
Georgia Gulf	19.0%	1
Arco Chemical	18.1	3
Vista Chemical	16.8	4
International Flavors	15.4	2
Dow Chemical	15.2	7
Aristech	15.0	11
Quantum Chemical	12.3	24
Ethyl	11.9	6
Loctite	11.2	8
Betz Laboratories	11.1	5

. . . and for first nine months of 1988

Sales

Rank 1987		$ Millions	Rank 1987
1	Dow Chemical	$12,383.0	1
2	Monsanto	6,412.0	2
3	Union Carbide	6,185.0	3
4	W. R. Grace	4,134.5	4
5	American Cyanamid	3,488.9	5
6	Quantum Chemical	2,379.8	7
7	Herculer	2,053.0	6
8	Arco Chemical	1,955.0	11
9	Rohm & Haas	1,940.4	8
10	Air Products	1,849.0	9

Earnings

	$ Millions	Rank 1987
Dow Chemical	$1775.0	1
Monsanto	546.0	2
Union Carbide	501.0	3
Arco Chemical	360.0	5
Quantum Chemical	285.4	11
American Cyanamid	242.8	4
Rohm & Haas	187.8	6
Ethyl	172.2	7
B. F. Goodrich	168.4	14
Air Products	158.4	8

Profitability

	Earnings as % of sales	Rank 1987
Georgia Gulf	27.4%	1
Aristech	19.0	14
Arco Chemical	18.4	3
Vista Chemical	16.1	11
International Flavors	16.0	2
Dow Chemical	14.3	9
Quantum Chemical	12.0	21
Ethyl	11.5	4
Betz Laboratories	10.8	5
Nalco Chemical	10.6	7

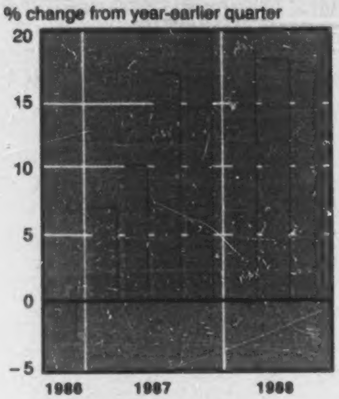
Note: For 30 chemical companies listed on page 26. a After taxes.

Chemical industry 1988 third-quarter results

- **Sales were up 17%**
- **Earnings climbed 65%**
- **Profit margins at 9.7%**
- **Production rose 8.6%**
- **Prices soared 10%**

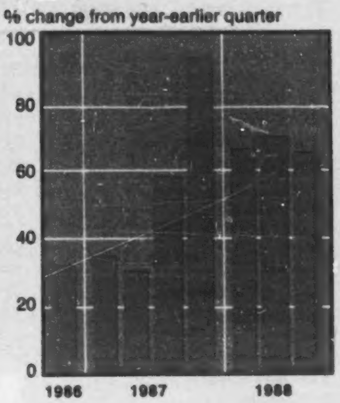
Sales

% change from year-earlier quarter



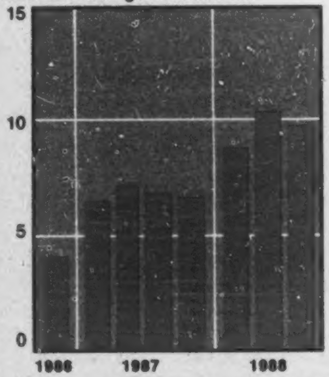
Earnings

% change from year-earlier quarter



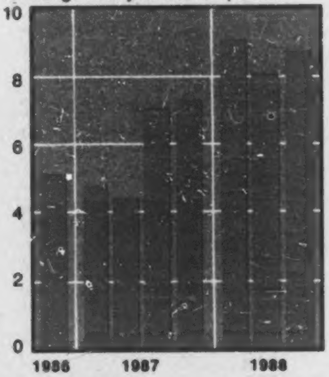
Profit margins

After-tax earnings as % of sales



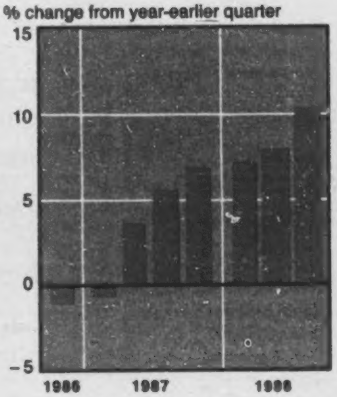
Production

% change from year-earlier quarter



Prices

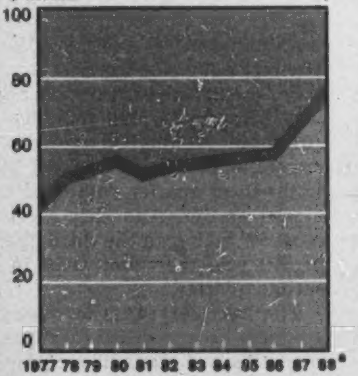
% change from year-earlier quarter



Sales in 1988 likely will climb about 17% while earnings will soar 65%, causing profits margins to move up to 9.5%

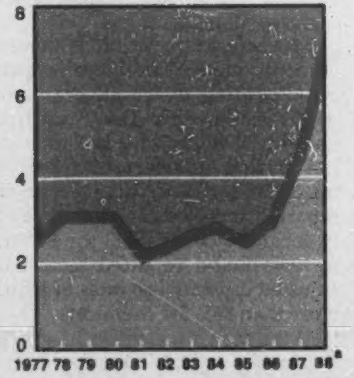
Annual sales

$ Billions



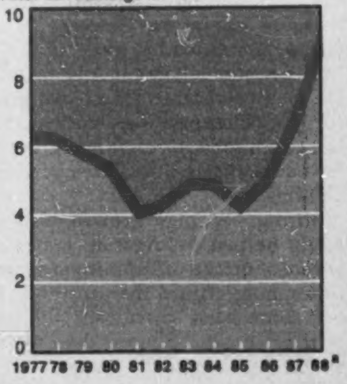
Annual earnings

$ Billions



Annual profit margins

After-tax earnings as % of sales



Note: All sales, earnings, and profit margin data are based on combined results of 30 companies listed on page 26. a C&EN estimates.

Third-quarter earnings for 30 major chemical firms soared 65% to $1.89 billion

	THIRD-QUARTER 1988						NINE-MONTHS 1988			
	Sales	Earnings[a]	Change from 1987		Profit margin[b]		Sales	Earnings[a]	Change from 1987	
	($ millions)		Sales	Earnings	1988	1987	($ millions)		Sales	Earnings
Air Products[c]	$ 622.0	$ 50.4	14%	29%	8.1%	7.2%	$ 1,849.0	$158.4	16%	31%
American Cyanamid[c]	1,094.1	64.1	5	17	5.9	5.3	3,488.9	242.8	11	19
Arco Chemical[c]	696.0	126.0	38	91	18.1	13.1	1,955.0	360.0	35	85
Aristech	278.0	41.6	16	122	15.0	7.8	806.7	153.3	19	217
Betz Laboratories	114.7	12.8	15	19	11.1	10.8	332.4	36.0	16	18
Cabot[c]	400.1	4.0	16	−47	1.0	2.2	1,289.8	39.0	30	−6
Chemed	146.7	6.6	45	9	4.5	6.0	354.5	17.2	22	10
Crompton & Knowles	90.4	3.9	54	48	4.4	4.5	232.4	12.6	30	45
Dow Chemical[c]	4,150.0	632.0	24	92	15.2	9.8	12,383.0	1775.0	27	99
Ethyl[c]	522.6	62.2	19	34	11.9	10.5	1,496.0	172.2	20	23
First Mississippi	81.9	4.5	4	−27	5.5	7.7	235.1	19.2	−2	6
H. B. Fuller	176.7	5.8	14	−26	3.3	5.1	504.1	16.3	14	−12
Georgia Gulf	278.7	53.1	58	90	19.0	15.8	508.8	139.2	37	146
B. F. Goodrich[c]	640.4	68.8	21	143	10.7	5.4	1,799.0	168.4	21	182
W. R. Grace[c]	1,390.4	50.6	26	24	3.6	3.7	4,134.5	147.5	29	66
Hercules[c]	686.9	32.2	5	−36	4.7	7.7	2,053.0	119.3	2	137
International Flavors	200.1	30.7	7	13	15.4	14.5	658.3	105.4	16	23
International Minerals	217.6	11.3	−49	−49	5.2	5.3	813.1	72.9	−39	68
Loctite	106.4	11.9	13	35	11.2	9.4	362.2	35.3	29	31
Lubrizol	263.9	24.7	13	31	9.4	8.1	841.6	79.5	9	16
Monsanto[c]	2,022.0	116.0	6	16	5.7	5.3	6,412.0	546.0	11	39
Nalco Chemical	248.8	26.9	15	32	10.8	9.4	732.2	77.9	20	34
Olin[c]	540.0	19.0	15	27	3.5	3.2	1,685.0	77.0	18	24
Pennwalt	243.2	7.7	18	31	3.2	2.8	760.1	35.0	20	32
Petrolite	71.7	2.5	5	−32	3.5	5.4	227.2	10.9	13	−8
Quantum Chemical[c]	812.4	99.8	33	262	12.3	4.5	2,379.8	285.4	30	264
Rohm & Haas[c]	619.8	49.8	15	27	8.0	7.3	1,940.4	187.8	16	18
Union Carbide[c]	2,108.0	213.0	22	188	10.1	4.3	6,185.0	501.0	22	140
Vista Chemical	197.6	33.2	19	84	16.8	10.9	599.5	96.6	25	142
Witco[c]	402.7	20.0	9	13	5.0	4.8	1,201.9	83.0	13	65
Total 15 larger companies	**$16,707.4**	**$1607.9**	**18%**	**72%**	**9.6%**	**6.6%**	**$50,252.3**	**$4862.8**	**20%**	**77%**
Total 15 smaller companies	**$ 2,716.4**	**$ 277.2**	**8%**	**35%**	**10.2%**	**8.2%**	**$ 7,968.2**	**$ 907.3**	**8%**	**63%**
GRAND TOTAL	**$19,423.8**	**$1885.1**	**17%**	**65%**	**9.7%**	**6.9%**	**$58,220.5**	**$5770.1**	**18%**	**75%**

a After-tax earnings from continuing operations, excluding significant extraordinary and nonrecurring items. b After-tax earnings as a percentage of sales. c One of the 15 larger companies.

in some cases are very high. And the high capacity utilization rates increase operating efficiencies at chemical companies, thus increasing earnings leverage. Add to this the relatively stable price conditions for petrochemical feedstocks, and the conditions for earnings growth far outpacing that for sales become obvious.

Strong earnings growth also is being helped by overseas markets, where shortage of supplies is sometimes more critical than in the U.S. For some basic chemicals, the export price can be more than twice the domestic price these days.

To meet the demand, production of chemicals and allied products in the third quarter rose almost 9% over the same period in 1987, according to government figures. The increase in output has pulled capacity utilization up considerably to more than 88% in the third quarter, according to the government's theoretical models. This is up from both the third quarter last year and the second quarter this year. In third-quarter 1987, the government reported capacity use at about 84%. In second-quarter 1988, the Federal Reserve Board reported seasonally adjusted capacity use rates of a little more than 86% for chemicals.

At the same time, prices have been increasing rapidly as supplies remain tight. The Labor Department's figures show that chemical prices in the third quarter were up more than 10% on a year-to-year basis. From the second quarter to the third quarter, prices, according to government data, increased 3.3% for chemicals and allied products.

For the narrower industrial chemicals category, which includes the commodity chemicals, prices increased an even more dramatic 14.5% in the third quarter, compared with a year earlier. And they were almost 5% higher in the third quarter of this year than they were in the second quarter.

The recovery in the chemical economy has proceeded long enough that corporate planners are now beginning to think that it is real. One indication is a spate of new plant announcements coming from chem-

E-MONTHS 1988		12-MONTH RUNNING DATA			
Profit margin[b]		Change from 1987		Profit margin[b]	
1988	1987	Sales	Earnings	1988	1987
8.6%	7.6%	14%	34%	8.8%	7.5%
7.0	6.5	10	22	6.7	6.1
8.4	13.5	34	93	17.5	12.2
9.0	7.1	23	103	11.5	7.0
0.8	10.7	16	22	10.7	10.2
3.0	4.2	29	−8	3.3	4.7
4.9	5.4	18	13	4.8	5.0
5.4	4.8	25	45	5.4	4.6
4.3	9.1	26	101	13.3	8.4
1.5	11.2	20	21	11.4	11.3
8.2	7.5	6	25	6.9	5.9
3.2	4.2	13	−1	3.6	4.1
7.4	15.3	51	156	17.8	10.5
9.4	4.0	16	110	7.3	4.0
3.6	2.8	28	265	3.7	1.3
5.8	2.5	3	−18	6.2	7.8
6.0	15.1	18	23	15.1	14.4
9.0	3.2	−27	238	8.5	1.8
9.8	9.7	19	35	10.5	9.3
9.4	6.9	10	21	8.0	7.2
8.5	6.8	12	42	7.1	5.6
0.6	9.5	20	40	10.4	8.9
4.6	4.3	20	39	4.3	3.7
4.6	4.2	3	10	4.4	4.1
4.8	5.9	14	−5	4.8	5.8
2.0	4.3	32	225	11.2	4.6
9.7	9.5	16	15	9.1	9.1
8.1	4.1	20	135	6.5	3.3
8.1	8.4	28	151	15.7	8.0
6.9	4.7	13	24	5.1	4.7
0.7%	6.6%	18%	74%	8.6%	5.9%
1.4%	7.6%	20%	56%	11.2%	8.6%
9.9%	6.7%	18%	70%	9.0%	6.2%

ical companies that promise vastly increased capacity in some basic chemicals such as ethylene by the early 1990s. Companies also seem to have revised their short-term capital expenditures as well. A survey by the Commerce Department shows that capital spending for chemicals and allied products this year is expected to increase 12.5% over 1987 levels. A survey a few months earlier showed that capital spending for chemicals would rise a lesser 11.7% in 1988.

However, until those new plants come on stream early in the next decade, the supply situation for many commodity chemicals, and especially petrochemicals, likely will remain tight. However, this tightness will constrain growth in downstream polymers, such as polyethylene.

For the third quarter, almost everything was looking good. Demand was good for many inorganic commodity chemicals. And chemical company executives were praising demand in all areas of their businesses. However, in many respects, petrochemicals were the key. To determine how petrochemical performance added to the chemical earnings picture, it is best to look at the chemical operations of the oil companies, which are based largely on petrochemicals.

In the third quarter, combined earnings from chemical operations at six major oil firms—Amoco, Atlantic Richfield, Exxon, Mobil, Texaco, and Unocal—more than doubled, rising 131% from the comparable period last year to $923 million. This is even better than they had been doing. For the first nine months, combined earnings for these companies increased 106% to $2.54 billion. And this is without the results of Occidental Petroleum, which added Cain Chemical to its results in May, thus increasing its earnings in the third quarter 478% to $283 million and its nine-month results 138% to $622 million. This is, of course, without restating prior results to take into account the acquisition.

Other chemical products did not perform nearly so well as petrochemicals, however. Thus overall chemical company earnings were largely much lower than those recorded by just petrochemical operations at oil companies.

But, as a rule, they were good. Earnings for the 30 chemical companies regularly surveyed by C&EN rose 65% to a total of $1.89 billion. Sales increased 17% to a total of $19.4 billion. The average profit margin (earnings as a percentage of sales) increased to 9.7% from 6.9% in last year's third quarter, but dropped slightly from the second quarter's 10.3%.

In terms of growth, the larger firms on the list far outperformed the smaller companies, but they still lag in profitability, albeit slightly. Earnings for the 15 larger companies increased 72% to a combined $1.61 billion on a sales rise of 18% to $16.7 billion. The smaller 15 firms' earnings rose 35% to $277 million on a sales increase of just 8% to $2.72 billion. The smaller earnings rise may in part be due to the smaller firms' inability to cover rising raw material costs with price increases. It is also due in part to the inclusion of International Minerals & Chemical, which has spun off its fertilizer operations without restating past results. If IMC is excluded from the small company tally, earnings for the 14 remaining firms rose an average 45%—still well below the increase for the larger companies.

Ground rules for C&EN earnings analysis

C&EN's quarterly report on financial performance of the U.S. chemical industry contains data from the 30 largest U.S. basic chemical producers and from 25 oil and diversified companies, each with more than $250 million in annual chemical sales.

To be included in the table of basic chemical producers, a company must derive at least 50% of its sales from chemicals. That is why Du Pont, for example, is included in the table of diversified manufacturers.

In referring to chemical sales, C&EN means those chemicals whose molecular composition has been changed in the course of manufacture. Its chemical sales include those of traditional categories of basic petrochemicals and inorganics, organic intermediates and inorganic chemicals, polymers such as plastics and fibers, agricultural chemicals, and specialty chemicals.

In listing earnings, the survey gives after-tax income for continuing operations before nonrecurring items and extraordinary charges. Foreign currency translations are included.

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For the first nine months, the situation is similar. For the 30 total companies, combined earnings increased 75% to $5.77 billion on a sales rise of 18% to $58.2 billion. Profit margins improved to 9.9% from 6.7% through the first three quarters of 1987. For the larger companies, earnings rose 77% to a total of $4.86 billion, and sales rose 20% to $50.3 billion. Profit margins for these firms averaged 9.7%, up from 6.6% in the first nine months last year.

For the smaller firms, earnings rose 63% through the first nine months to $907 million. But sales for these companies increased just 8% to $7.97 billion. Since the earnings increase was so much greater than that for sales, however, the profit margins growth was slightly stronger than for the larger firms, rising to 11.4% in the first nine months of this year from 7.6% in the comparable period of 1987.

For the third quarter, the best earnings increase was recorded by Quantum Chemical, which also is basically a petrochemicals producer. Quantum's earnings jumped 262% to $99.8 million on a sales gain of 33% to $812 million. Quantum chairman John Hoyt Stookey attributes the increase in sales and earnings from operations in the quarter principally to continued strong demand with generally higher selling prices and improved profit margins in the petrochemical business.

A bright spot for the quarter is that agricultural chemicals sales have begun to recover from the plunge caused by the farm recession and are showing few effects of the summer drought. Monsanto notes that its strong third-quarter results were

Earnings at pharmaceutical companies improve

Like their chemical brethren, pharmaceutical companies reported improved earnings in the third quarter, but unlike chemical companies, the increase was only modest and profit margins did not increase appreciably.

Third-quarter earnings for 12 major U.S. drug companies surveyed by C&EN increased 11% from last year's third quarter to $1.56 billion. The increase was only slightly higher than that for sales, which rose 10% to $11.7 billion. Consequently, the average profit margin for the group was 13.3%, essentially the same as the 13.2% margin in third-quarter 1987.

Previous quarters had been better this year, improving the results for the first nine months. During that period, earnings for the group rose 15% to a total of almost $4.70 billion, and sales increased 12% to an aggregate $34.7 billion. Thus, nine-month profit margins for the group rose to an average 13.6% from 13.2% in the first nine months of last year.

All but three of the companies reported earnings gains during the quarter. The biggest increase was at Merck, whose earnings climbed 31% to $312 million on a 12% sales increase to $1.47 billion. Merck's profit margin improved to 21.2% from 18.2% in last year's third quarter. Says Merck chairman P. Roy Vagelos: "Sales growth for the first nine months was led by new products. Strong unit volume gains were registered by both our domestic and international operations."

Another solid gainer was Schering-Plough, whose third-quarter earnings climbed 28% to $94.4 million on a 9% sales gain to $724 million. The company attributes stronger third-quarter performance to its worldwide pharmaceuticals business, sales of which rose 14%, and to continued growth by U.S. consumer businesses.

Upjohn's earnings grew 20% to $89.6 million on a 7% sales gain to $652 million. The company was helped by an above-average sales growth of 19% in its worldwide agricultural products business. Animal health products registered good sales gains in foreign markets. And the firm says that continued sales growth in the U.S. for Naxcel, its product for treatment of bovine respiratory disease introduced during the first quarter, was offset by decreases in sales of other animal health products. Upjohn claims excellent growth in domestic agronomic seed sales, and it says vegetable seed sales made excellent gains over the third quarter in 1987, particularly in Europe.

	THIRD-QUARTER 1988						NINE-MONTHS 1988					
	Sales	Earnings	Change from 1987		Profit margin		Sales	Earnings	Change from 1987		Profit margin	
	($ millions)		Sales	Earnings	1988	1987	($ millions)		Sales	Earnings	1988	1987
American Home Products	$1415.2	$240.7	9%	11%	17.0%	16.7%	$4199.6	$693.5	10%	10%	16.5%	16.5%
Baxter International	1708.0	85.0	8	−6	5.0	5.7	5036.0	267.0	10	15	5.3	5.1
Eli Lilly	940.6	171.4	11	19	18.2	17.0	3027.4	585.3	11	18	19.3	18.1
Merck	1468.8	311.8	12	31	21.2	18.2	4405.4	899.5	20	33	20.4	18.4
Pfizer	1382.9	216.8	7	17	15.7	14.3	4017.2	649.7	10	17	16.2	15.2
Rorer Group	244.6	15.2	9	12	6.2	6.0	716.4	34.9	11	10	4.9	4.9
Schering-Plough	724.4	94.4	9	28	13.0	11.1	2229.5	296.9	10	23	13.3	11.8
SmithKline Beckman	1172.7	97.1	6	−35	8.3	13.6	3472.1	362.4	11	−15	10.4	13.7
Squibb	679.5	123.0	21	13	18.1	19.5	1921.0	328.0	28	20	17.1	17.5
A. H. Robins	264.1	23.4	16	−12	8.9	11.6	692.8	45.5	12	−25	6.6	9.7
Upjohn	651.8	89.6	7	20	13.7	12.3	2035.8	272.8	9	17	13.4	12.5
Warner Lambert	1031.4	87.7	16	16	8.5	8.5	2910.5	262.8	14	14	9.0	9.0

Earnings increase for oil and diversified companies

	THIRD-QUARTER 1988						NINE-MONTHS 1988					
	Sales	Earnings[a]	Change from 1987		Profit margin[b]		Sales	Earnings[a]	Change from 1987		Profit margin[b]	
	($ millions)		Sales	Earnings	1988	1987	($ millions)		Sales	Earnings	1988	1987
OIL AND GAS COMPANIES												
American Petrofina	$ 696.1	$ 67.2	5%	217%	9.6%	3.2%	$ 1,959.2	$ 132.0	8%	89%	6.7%	3.8%
Amoco	5,948.0	552.0	3	34	9.3	7.2	17,878.0	1688.0	7	72	9.4	5.9
Ashland	2,098.6	66.2	5	1	3.2	3.3	6,108.0	143.7	13	35	2.4	2.0
Atlantic Richfield	4,592.0	391.0	3	24	8.5	7.1	13,776.0	1192.0	12	35	8.7	7.2
Chevron	7,200.0	420.0	−6	41	5.8	3.9	22,000.0	1593.0	1	57	7.2	4.7
Exxon	21,888.0	1225.0	0	15	5.6	4.9	65,522.0	3880.0	6	18	5.9	5.3
Kerr-McGee	659.9	30.5	−5	40	4.6	3.1	2,053.6	76.6	4	11	3.7	3.5
Mobil	13,116.0	557.0	0	69	4.2	2.5	40,987.0	1590.0	10	92	3.9	2.2
Occidental Petroleum	4,913.0	108.0	16	135	2.2	1.1	14,133.0	306.0	11	90	2.2	1.3
Phillips Petroleum	2,850.0	215.0	2	594	7.5	1.1	8,630.0	515.0	8	25,650	6.0	0
Sun Co.	2,460.0	72.0	−2	−47	2.9	5.4	7,280.0	228.0	1	−14	3.1	3.7
Texaco	8,689.0	239.0	−3	121	2.8	1.2	26,799.0	707.0	3	111	2.6	1.3
Unocal	2,581.0	97.0	0	234	3.8	1.1	7,432.0	224.0	5	47	3.0	2.2
DIVERSIFIED MANUFACTURERS												
Allied-Signal	2,864.0	119.0	7	29	4.2	3.4	8,902.0	367.0	9	17	4.1	3.8
Borden	1,874.2	91.9	12	16	4.9	4.7	5,260.2	218.0	12	17	4.1	3.9
Du Pont	7,985.0	461.0	5	2	5.8	6.0	24,476.0	1690.0	9	25	6.9	6.0
Eastman Kodak	5,029.0	435.0	28	10	8.6	10.1	12,491.0	679.0	28	−5	5.4	7.3
Engelhard	614.4	16.9	0	15	2.8	2.4	1,655.6	44.5	−5	−4	2.7	2.8
FMC	798.2	31.2	9	16	3.9	3.7	2,404.8	93.2	5	2	3.9	4.0
Ferro Corp.	247.7	11.8	15	42	4.8	3.9	748.2	34.9	17	56	4.7	3.5
3M	2,689.0	296.0	9	19	11.0	10.1	8,002.0	882.0	13	26	11.0	10.0
Morton-Thiokol	601.5	41.3	19	2	6.9	8.1	1,829.1	120.8	16	7	6.6	7.2
PPG Industries	1,361.0	112.9	8	24	8.3	7.2	4,185.0	365.3	9	30	8.7	7.3
Vulcan Materials	298.6	49.4	11	6	16.5	17.2	785.7	110.9	16	17	14.1	14.0
Tyler	172.8	3.8	6	−50	2.2	4.6	496.9	13.8	6	−22	2.8	3.8

a From continuing operations excluding major nonrecurring and extraordinary items. b Earnings as a percentage of sales.

led by Monsanto Agricultural Co. as well as Monsanto Chemical Co., both operating units of the corporation. The agricultural businesses were buoyed by sales of Roundup herbicide and Alimet poultry feed supplement.

Overall, for the three-month period, Monsanto's earnings from crop chemicals increased 17% to $82 million, while sales increased 12% to $307 million. Crop chemicals make up about 43% of Monsanto's operating income, but just 15% of its sales.

Pesticides have begun a financial comeback at Rohm & Haas, although physical volume of agricultural chemicals sales in the third quarter were off 3% from the same period a year earlier, indicating stronger selling prices. Sales of agricultural chemicals in the quarter were up 14% to $59.7 million and net earnings from those operations moved from a loss of $1.3 million to a slight gain of $100,000.

American Cyanamid does not break out operating results for its agricultural chemicals, but did note in an announcement, "Athough the major portion of the selling cycle for the agricultural group occurs in the first six months of the year, worldwide sales of the group were higher in the third quarter than in the comparable period last year; and, as a consequence, operating results improved."

Most companies see the strong performance carrying through the remainder of the year. Dow Chemical's financial vice president Enrique C. Falla says, "The strong fundamentals and momentum are strong, positioning the industry and Dow for a strong fourth-quarter performance. Dow has already recorded net earnings per share of $9.32 year-to-date, which is 44% higher than the $6.47 set for all of 1987. Obviously, 1988 is a record year for Dow."

Union Carbide chairman Robert D. Kennedy says the strong performance reflects the upswing for chemicals generally and also attributes some of the performance to the company's position in some markets and low-cost manufacturing in key product areas. He says that he expects fourth-quarter earnings to be about the same as or slightly higher than those in the third quarter.

And Aristech chairman Thomas Marshall says with the current strength in both the domestic and export markets and Aristech's increased capacity on stream, the prospect is for an outstanding performance for the full year of 1988. ☐

Many University Research Facilities Need Repairs

National Science Foundation survey finds that more schools are deferring lab construction because they can't secure funding for renovation

In the first, full-scale survey of its kind, the National Science Foundation has discovered that nearly 60% of space currently used for academic research is in need of repair. And, because of problems in securing funding for renovation, the survey finds that universities and colleges are deferring more and more lab construction as time goes on.

The NSF study on scientific and engineering research facilities was mandated by Congress in 1986. To be done every other year, the study is a response to increasing pleas from academic institutions for more federal funding to keep laboratories up-to-date and functioning. Although a quick-response survey of research institutions was done by NSF in 1986, the 1988 survey is its first complete study.

One of the things NSF determined is that there are about 114 million sq ft of research space at U.S. academic institutions. Nearly all of this space is at doctorate-granting universities, and NSF says that the top 50 R&D universities account for 50% of all the research space. Nearly 80% of the research space is taken up by five science and engineering fields: biology, medicine, agriculture, physical science, and engineering. These five disciplines also account for about 80% of total academic R&D expenditures.

According to responses received from the survey, only about one fourth of the space currently used for research is suitable for the most sophisticated research in its field. Almost 40% of research space is in need of limited or major repair to be used effectively. Consequently, the survey found that institutions plan to spend about $777 million in 1988 and 1989 for repairs and renovation of lab space. This represents work on only 9% of lab space, meaning that only a small portion of the labs needing repair will be worked on.

In fact, the survey found that one of the most common themes mentioned by academic officials is the backlog of necessary repairs and renovations. They say that there is continued deferral of repairs and that this is compromising the quality of the research space. NSF reports that total expenditures for repairs, on a square footage basis, are declining, indicating that the level of deferred renovations is increasing over time.

Institutions reported they expect to spend nearly $3.4 billion on construction of new facilities. Responses to the survey indicate that this increased building of labs is caused more by rapidly changing technical and regulatory requirements than by the institutions' desire to expand their research space. One of the areas often cited is the extremely high cost of building animal research facilities under today's federal regulations.

According to NSF, renovation backlogs and the need for more research space were cited about one third of the time as causing problems to the university's or college's research program. Physical science administrators in particular mentioned that the lack of excellent facilities can hurt in recruiting top faculty and graduate students to a program. Lack of facilities also limits the numbers and types of research projects that can be undertaken. In some instances, universities are losing qualified researchers because of inadequate lab space.

Universities have to rely on a variety of sources for money to spend on renovations and new construction. NSF reports that public institutions get their largest percentage of funds from state and local governments. These sources will provide a little more than $1 billion over the next two years. Private schools rely mostly on private donations and on tax-exempt bonds, from which more than $300 million

Universities received most of their lab funds from state and local governments in 1986 and 1987

$ Millions	Construction		Repair/renovation	
	Public	Private	Public	Private
Federal government	$ 41.0	$106.7	$ 13.2	$ 14.4
State and local government	757.8	25.1	227.9	6.7
Private	259.9	227.6	15.0	90.9
Institutional funds	110.1	181.2	156.3	174.2
Tax-exempt bonds	192.8	124.5	25.8	126.8
Other debt	2.4	0.7	0.3	3.7
Other sources	0.2	33.0	0.2	7.5
TOTAL	$1364.2	$698.7	$438.8	$424.1

Note: Totals may not add because of rounding. Source: National Science Foundation will be raised for new construction in the same time period. The proportion of federal support for these institutions is just 7% of the total for construction and less than 5% for repair, or about $227 million for everything.

One major change in recent years has been the federally imposed limit on funds that a university can raise with tax-exempt bonds. The 1986 tax reform bill put a ceiling of $150 million on outstanding tax-exempt bonds for each institution. NSF reports that at the time of its survey, 10% of the private research-performing institutions had already reached that cap, and another 4% were expected to top out within the next two years. Among the private schools, 20% had already reached the $150 million limit.

NSF did not analyze the impact on universities of not being able to finance construction or renovation through such debt tools, but it is easy to see that without the bonds, schools will have to rely more on government support (which may be decreasing) or on donations from individuals. Another option would be to increase efforts to get Congress to support construction programs for individual projects outside the normal funding mechanisms, the so-called pork-barrel science method (C&EN, July 18, page 7).

Copies of the NSF report, titled "Scientific & Engineering Research Facilities and Universities & Colleges: 1988," can be obtained from the Division of Science Resources Studies, National Science Foundation, 1800 G St., N.W., Room L-602, Washington, D.C. 20550. The publication number is NSF 88-320.

David Hanson

Institute eyed to train biotech patent examiners

A series of meetings is now under way between the Patent & Trademark Office and the Industrial Biotechnology Association that may culminate next March with the formation of a new Biotechnology Institute. The institute would provide formal technical and legal education programs for PTO's Group 180 (biotechnology) patent examiners.

IBA approached PTO with the idea for setting up the institute this past summer because it was concerned about the current backlog of 6500 biotechnology applications and about the five months longer, on average, that it takes to get a biotechnology application through the patent approval process than it does other applications.

IBA president Richard D. Godown explains that without patent protection "the biotechnology industry cannot compete or maintain its competitive position in international arenas. . . . Biotechnology doesn't want to be kept out of the race because there aren't enough qualified, well-trained patent examiners." PTO was receptive to the idea, in part because, as a spokesman said, it's always helpful to have outside experts bring in fresh ideas and provide new input to the examiners.

According to Godown, the institute would be under the control of the patent office but would be able to draw upon the expertise not only of IBA member companies but also the patent bar and academic and government experts in the field of biotechnology for help in educating the Group 180 examiners. This assistance could include, among other things, daylong training seminars for new examiners and continuing education programs for examiners already on the PTO staff. IBA also would assist the patent office in updating its library of biotechnology publications and facilitating visits by Group 180 examiners to biotechnology companies.

Godown says he really doesn't know how much the institute would cost, but he expects that industry would share part of the costs, since it is permissible for PTO to accept outside donations to its examiners training fund. And there will be quite a few examiners to train. PTO started the year with 75 biotechnology examiners and expects to have hired 36 more by the end of the year. It intends to add an additional 20 by fiscal 1990, which as Godown puts it, is "a nice increase."

Janice Long

Federal Alert—new regulations

This C&EN listing highlights regulations published in the Federal Register *from Aug. 1 to Oct. 31. Complete information is available on the page numbers cited.*

PROPOSED

Environmental Protection Agency—Establishes worker protection standards for employees cleaning up hazardous waste sites under Superfund; comments by Nov. 16 (Oct. 17, page 40692).

Sets procedures for changing rules on permitting pesticide residues on processed foods, including policy on Delaney Clause paradox; comments by Dec. 19 (Oct. 19, page 41126).

Occupational Safety & Health Administration—Seeks comments on feasibility and usefulness of generic standards on exposure monitoring for toxic substances; comments by Dec. 27 (Sept. 27, page 37591).

FINAL

Commerce Department—Makes numerous changes to list of export-controlled products, including minerals, chemicals, and petroleum products; effective Sept. 14 (Sept. 14, page 35459).

Environmental Protection Agency—Freezes production and consumption levels of certain chlorofluorocarbons and brominated compounds to limit stratospheric ozone depletion; effective with onset of Montreal protocol (Aug. 12, page 30566).

Requires producers of pesticide active ingredients to register their production establishments and submit annual production reports; effective after 60 Congressional working days (Sept. 8, page 35056).

Finalizes revisions to general pretreatment regulations for discharges into publicly owned water treatment facilities; effective Nov. 16 (Oct. 17, page 40562).

Promulgates financial responsibility requirements for owners and operators of underground storage tanks containing petroleum; effective Jan. 24, 1988 (Oct. 26, page 43322).

Nuclear Regulatory Commission—Provides for licensing of storage of spent nuclear fuel and high-level radioactive wastes at monitored retrievable facilities; effective Sept. 19 (Aug. 19, page 31651).

Occupational Safety & Health Administration—Delays effective date of standard for exposure to formaldehyde for all laboratories except anatomy, histology, and pathology labs; effective Jan. 1, 1989 (Sept. 1, page 33807).

Requires that union representatives must show health causes to get permission to see employee medical records, makes other changes to health records access rule; effective Nov. 28 (Sept. 29, page 38140).

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Analytical instrument market
continues to soar
Page 17

NOVEMBER 21, 1988

CHEMICAL & ENGINEERING NEWS

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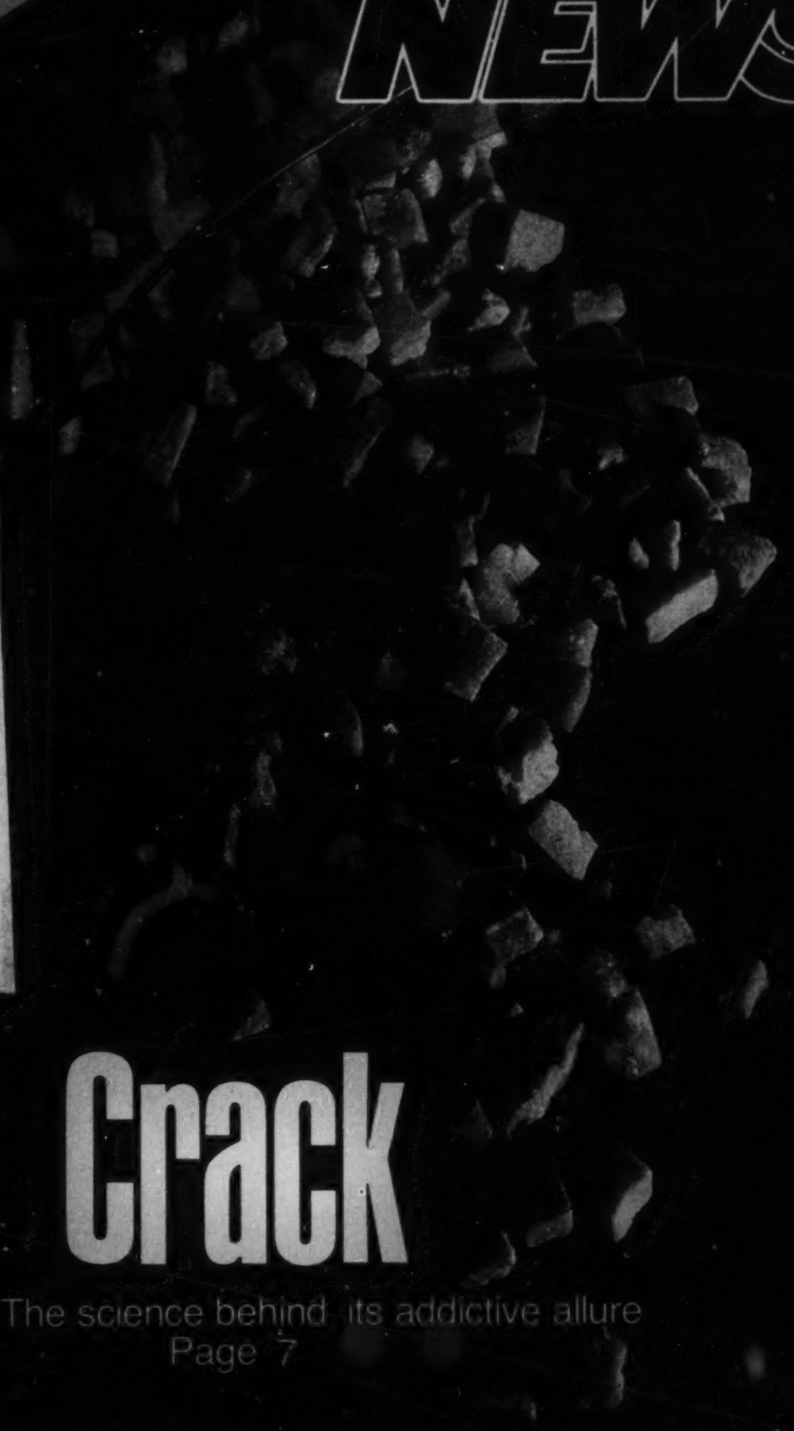

Crack

The science behind its addictive allure
Page 7

Volume 66, Number 47
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CHEMICAL & ENGINEERING NEWS

NOVEMBER 21, 1988

News of the Week

- **Visit to the U.S. by Soviet Nobel Peace Prize Laureate and human rights leader Andrei D. Sakharov included meeting with Edward Teller, other dramatic and symbolic moments.** **Page 4**
- **Polychlorinated biphenyls have been proven to be biodegradable, confirming the hypothesis they are being dechlorinated in Hudson River sediments.** **Page 5**
- **Japanese petrochemical industry delegation visits ACS as part of trip to study chemical public information programs in the U.S.** **Page 5**
- **Du Pont will market mice with cancer-causing genes for cancer research, marking the first commercialization of genetically engineered animals.** **Page 6**
- **Expanded superconductor R&D program is sorely needed, or U.S. faces prospects of purchasing these materials for defense purposes from foreign sources such as Japan, task force finds.** **Page 6**

Cover: Packet of crack cocaine at Ft. Lauderdale police station. Photo by Steve Starr/The Picture Group

Letters 2

Concentrates
Business 15
Government 22
Science/Technology 26

The Departments
ACS Comment 35
Newscripts 60

Business

The market for analytical instruments continues its fast growth, sparked by increasing demand for chemical analysis, strong exports, new and better techniques. **Page 17**

Japanese chemical industry's current impressive performance stems from the robust domestic demand for basic chemical products. **Page 21**

Government

Election causes little change in Congress, with the Democrats winning a few more House seats and one additional Senate seat. **Page 23**

Political battle begins over decision to site Superconducting Super Collider in Texas, as representatives from rejected states question selection process. **Page 24**

Technology

Crucial role of supercomputers in materials science research is emphasized in a report by the National Research Council. **Page 27**

China plans to establish a network of 12 analytical chemistry laboratories. **Page 28**

Books

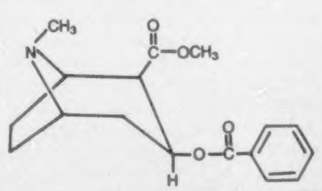
"Messengers of Paradise: Opiates and the Brain" by Charles Levinthal, relates story of the race for breakthroughs on the brain's endogenous opioid system. **Page 33**

ACS News

The society's fund-raising effort, Campaign for Chemistry, has a new chairman and is progressing toward its goals. **Page 36**

Awards

ACS award winners: Krigbaum, Lagowski, Levitt, Macfarlane, Mandelkern, Marks, Marsh, McLafferty, and Olah. **Page 41**



Cocaine

News Focus

Scientists struggling to understand and treat cocaine dependency are frightened by the dimension that crack cocaine has added to the problem of cocaine abuse. **Page 7**

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LETTERS

Exposure to carcinogens

SIR: This is a comment arising out of your article on proposed Environmental Protection Agency benzene rules (C&EN, Aug. 22, page 22).

The problem with setting rules for protecting human beings from possible carcinogens is that it is difficult to determine what the response of the human is to a particular chemical at particular levels. I believe that Homo sapiens is the toughest animal on Earth. This arises from our ancestors' multimillenia-long exposure to multiple carcinogens in smoky caves and their habit of eating everything that came to hand (that didn't eat them).

In the case of benzene, an experimental animal is available—the chemist. My generation of chemists was exposed to frequent encounters with benzene in chemistry labs over many years. It was regarded as a fine solvent for removing oily or tarry soil from the body or clothes with little regard to ventilation. Other materials such as carbon tetrachloride were treated similarly. Surveys of older chemists do not reveal atypical mortality.

This is not to say that acute exposures should be ignored, but as Bruce Ames of the University of California, Berkeley, has told us, we are chronically exposed to a much greater number of natural carcinogens (and have been for eons) than synthetic ones, and we should not go overboard in setting rules and regulations for the latter.

A. C. Nixon
Berkeley, Calif.

High school chemistry

SIR: Relative to the ACS Comment "ChemCom—an exciting new approach to teaching" (C&EN, Sept. 26, page 47), I offer my own high school chemistry teaching experience.

I obtained my B.S. in chemical engineering in 1928. During the depression years I taught in the fifth and sixth grades, then college general and organic chemistry, and received an M.S. in education. Thereafter, I worked in the protective coatings industry to eventually become the technical coordinator of the vice president of research and development, production and marketing, for the three plants of a Canadian firm.

Returning to the U.S. I taught physics and chemistry in high school for 14 years and community college chemistry for two of those years before I retired in 1973. I was fortunate to enter this profession at the time of Sputnik, and participated in the National Science Foundation's summer sessions in chemistry (Chemical Bond Approach, Chemstudy), physics (Physical Science Study Committee), and mathematics. However, it became apparent that, in the high school where I taught, more modes of teaching chemistry were desirable. So I developed and taught (1) Advanced Placement Chemistry, 12 to 16 students, who used a library of college chemistry texts for their presentation of selected pertinent topics and laboratory research into relevant objectives; (2) science-oriented chemistry, 24 to 26 students, with a more sophisticated high school chemistry text backed up by a high school chemistry library, and with an appropriate lab manual and problem exercise book; (3) liberal arts chemistry, 24 to 26 students, with a more general high school chemistry text and lab manual and library; and (4) "Living Chemistry," 16 to 20 students (nonacademic), with the text and lab manual, "Living Chemistry," supplemented by wider lab work (it was predominantly a lab course), to acquaint them with objects they meet in everyday life, a number of which they made in the lab. The second mode might have been separated into a chemistry/biology-oriented and a physics-oriented mode.

My requirements (appropriate to the mode) were demanding, yet my classes were readily filled and well attended (the parents played a role). And the appreciative comments of students (and their parents), after graduation, from all four modes indicated that many (if not all) did benefit by the divisions.

I realize that many high school systems cannot make such divisions because of population size, teacher availability, financial limitations. More individual or subgroup attention by the properly trained teacher, aided by mimeographed text and lab literature (perhaps supplied by ACS), with lab materials supplied by industry, and the assistance of chemistry-oriented (or advanced-placement level) students, might serve. The content would need to be updated periodically.

Those were challenging, rewarding years!

Hubert A. Kraus
Cinnaminson, N.J.

Correction

- Oct. 31, page 7: Arco Chemical's trial production run of superabsorbent fiber at Du Pont will be for 200,000 lb of fiber, not 2000 lb; a commercial-scale facility would produce an estimated 20 million lb of fiber per year, not 20,000 lb.

Analytical Instrumentation Market Growing Rapidly

Spurred by industry, academia, and government needs for increased chemical analysis, global sales have nearly doubled since 1983

Ann M. Thayer,
C&EN Northeast News Bureau

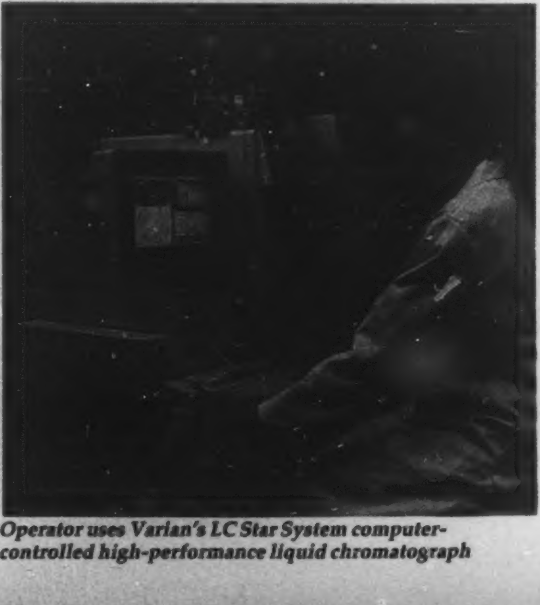
The market for analytical instruments is showing a strength only dreamed about as little as five years ago. Driven by the need for greater chemical analysis coming from quality control and government regulation, a robust export market, and new and increasingly sophisticated techniques, sales are increasing rapidly.

The analytical instrument business' worldwide sales are nearly double their value of five years ago, reaching $4.1 billion in 1987. Such growth is in stark contrast to the doldrums of several years ago when economic recession held back sales growth to little or nothing. In recent years, the instrumentation market has recovered, growing at nearly 9% per year, and it's expected to continue at this rate at least until the 1990s. With sales increases exceeding inflation, the industry has seen real growth demonstrating the important role of chemical instrumentation in areas such as research and development, manufacturing, defense, and the environment in a technologically advancing world.

Worldwide sales figures for analytical instruments have been compiled and analyzed in a study by the technical and marketing consulting firm of Alpert & Sutcliffe, located in Stamford, Conn. According to its figures, in the U.S. alone, 1987 purchases of instrument lines having broad, general application to chemical analysis totaled about $1.62 billion and likely will reach $1.76 billion in 1988 after the 8 to 9% growth expected. This does not include equipment designed solely for clinical use, process control or monitoring, or special applications. Although exact import and export figures for specific types of instruments are difficult to obtain, close observers of the analytical instrumentation market indicate that U.S. exports still outweigh imports, although not overwhelmingly.

Competition now comes from overseas producers who have become technologically mature, whereas the technology for scientific instrumentation was once rooted almost entirely in the U.S. Figures from *Analytical Instrument Industry Report*, a British bimonthly newsletter, show the U.S. supplying 40 to 45% of the world market, Europe 25 to 30%, and Japan more than 20%. Of the top worldwide instrument manufacturers—those having sales over $100 million per year—five are U.S., five are European, and four are Japanese, based on rankings from the report. The instrument industry is becoming increasingly global and the position of the U.S. as a leader is apparently eroding.

Japan has increased its share in the instrument market over the past few years by capitalizing on trends in automation, computerization, and robotics, possibly more so than through innovations in analytical techniques themselves. Although the Japanese are making significant inroads into the market, exact sales figures can be deceptive. For example, Gordon Wilkinson, editor and publisher of the *Analytical Instrument Industry Report*, says that higher rankings of the Japanese companies, such as Shimadzu (1987 sales of $350 million to $400 million), are due primarily to the appreciation of the yen since 1985. Actually, these companies have had difficulties in export sales for the very same reason. However, the Japanese dominate sales in their own regional market, importing only $200 million from the U.S. and Europe, while consuming about 75% of the nearly $1 billion Western Pacific market. Japan is also the biggest supplier to China, the second



Operator uses Varian's LC Star System computer-controlled high-performance liquid chromatograph

largest consumer in the Western Pacific arena.

In spite of this, suggests Nelson L. Alpert, director of Alpert & Sutcliffe, the U.S. instrument industry can remain robust by maintaining the practice of close communications between manufacturers and users of the instruments. He says that historically this strong foundation has kept the U.S. instrumentation industry somewhat immune to economic and trade variations and has allowed it to lead in innovations and developments in technology through the interaction with customers.

Certain forces driving the instrumentation market can be detected in an altogether prosperous chemical industry. The materials, environmental, biomedical research, biotechnology, and pharmaceuticals sectors of the chemical industry are thought to have tremendous potential as consumers of instruments for their R&D efforts. Pharmaceuticals, a high return-on-equity business, put a large percentage, about 10%, of nearly $38 billion in earnings back into R&D in 1987, as compared with an average of 4.5% for the chemical industry as a whole. Biotechnology companies, although showing little if any in the way of profits, are expected to boom in the next decade along with extensive R&D efforts.

In remarks made before a recent meeting of financial analysts, Allen J. Lauer, instrument group president of Varian Associates Inc., mentioned these influences on the market. He said that the focus of Varian's instrument group, which produces chromatographs and spectrometers for industrial, research, and government laboratories, is on broadening its product line in carefully selected technologies in an attempt to leave the company well-positioned to serve the faster-growing life science, pharmaceutical, and environmental markets.

Analytical instrument sales will reach $4.8 billion in 1989

$ Millions[a]	1989	1988	1987	1986	1985
MOLECULAR ANALYSIS					
UV/visible spectrophotometers	$ 242	$ 232	$ 221	$ 211	$ 202
Fluorescence spectrometers	75	69	61	54	48
Spectropolarimeters/ORD/CD	14	13	12	11	10
Fourier transform infrared	200	176	148	122	98
Dispersive infrared	59	58	58	62	64
Raman spectrometers	14	13	11	10	9
Near infrared	60	54	48	43	36
Nuclear magnetic resonance	199	181	165	148	133
Gas chromatographs	544	503	465	430	395
High-performance liquid chromatographs	782	714	646	580	513
Ion chromatographs	136	108	85	65	50
Liquid chromatographs	262	253	243	232	223
Voltammeters	24	23	22	21	20
Mass spectrometers	416	375	337	302	271
Thermal analyzers	126	115	104	94	86
Densitometers	49	47	45	42	39
Scintillation counters	55	52	49	46	45
Titrators	67	64	60	55	50
Automated flow analyzers	32	30	28	26	24
ELEMENTAL ANALYSIS					
Atomic absorption	183	174	166	158	148
Plasma emission	156	139	124	112	99
Arc/spark emission	101	96	92	86	80
Energy dispersive x-ray	137	124	112	102	94
Wavelength dispersive x-ray	97	95	92	90	88
X-ray diffraction	71	69	69	66	66
Electron spectrometers	139	125	113	102	94
Electron microprobes	34	31	29	26	26
Transmission electron microscopes	129	122	116	110	104
Scanning electron microscopes	205	187	169	152	142
pH/ISE systems	147	139	131	123	115
Organic elemental analyzers	87	81	76	70	65
TOTAL	$4812	$4462	$4097	$3751	$3437

[a] In actual dollars for 1985, 1986, and 1987. Estimates for 1988 and 1989 are based on June 1987 dollars and include inflation. **Source:** Alpert & Sutcliffe

Apparently, this philosophy is working. Sales for Varian's instrument group are up 20% from last year, with a projected total of $227 million in 1988 sales. This has been a strong rebound for Varian; it was only two years ago that plans were discussed to divest the company's instrument group. Since that time, the group has grown more than 30% with pretax earnings of $20 million, its largest profit in 25 years.

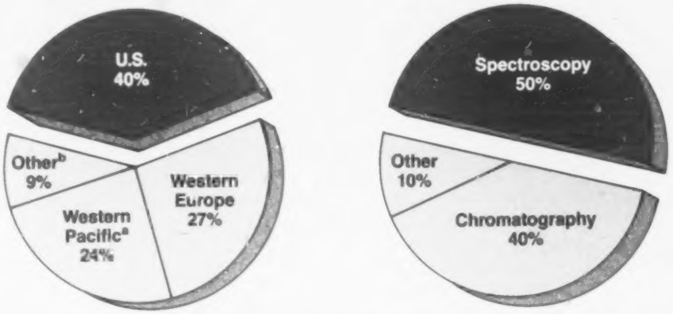
Similarly, Perkin-Elmer Corp., the world's largest instrument manufacturer (1988 sales expected to reach $484 million), is looking at growth in some of the same areas. Perkin-Elmer's chairman and chief executive officer, Horace G. McDonell, considers its 16% rise in 1988 sales to be especially significant "because growth was achieved in all geographic markets." And, he adds, "The Far East was especially outstanding, led by a 100% gain in orders for the year in Japan."

Meanwhile, sales for Hewlett-Packard Co., the second largest U.S. instrument maker, have more than doubled in the past five years to $388 million in 1987. The weak dollar has aided the U.S. instrument business and made exports more competitive on a price basis; however, the U.S. market itself is not always particularly strong. Much of the apparent growth based on dollar figures is evident for many manufacturers, Hewlett-Packard and Perkin-Elmer among them, with very large overseas markets.

Another factor affecting the market is the expanding demand for thorough, yet rapid, chemical analysis in industrial and research laboratories. This labor-intensive and time-consuming work and the lower cost of computers in the past decade have influenced the design and production of automated and com-

U.S. is largest analytical instruments buyer...

. . . and spectrometers are biggest sellers



Total 1987 global sales = $4.1 billion

a Includes Japan, China, and Australia. **b** Includes Canada, Latin America, India, the Mideast, U.S.S.R., and Eastern Europe. **Source:** Alpert & Sutcliffe

puterized analytical instrumentation. Computerization and automation are also becoming desirable for easy-to-operate, on-line process control and monitoring, quality control, and environmental testing. As big selling factors, many manufacturers now emphasize robotics, automation, software, computers, and the ability to interface equipment.

This trend is reflected in two ways. First, by the examples of Varian and Hewlett-Packard, both having nearly 50% of their R&D efforts in software development; Perkin-Elmer also focuses much of its effort on laboratory automation with its robotics hardware and with software systems for laboratory information management. And second, by the increased number of joint ventures or acquisitions that often combine instrumentation and computer technologies.

An example, but by no means the only one, is Perkin-Elmer. In the past two years it has broadened its base in chromatographic data handling and analysis through its acquisition of Nelson Analytical to form PE Nelson Systems, in biotechnology instrumentation through a joint venture with Cetus, and in environmental analysis through a joint venture with Sciex. Most recently, Perkin-Elmer and Digital Equipment Corp. have entered into a joint agreement for the marketing of laboratory information management systems.

Restructuring efforts are also hitting the instrument business. Currently involved in one is Beckman Instruments, the instrument division of SmithKline Beckman, which SmithKline is spinning off into a separate, publicly owned company. This has led to the sale of $5 million worth of Beckman shares, thereby decreasing SmithKline's interest in the company to 83%.

Analytical instrument sales in the U.S. are made chiefly to industry, followed by government and academia. Overall R&D spending in the U.S. has increased over the past decade to a level of $128 billion in 1988. Alpert indicates that increases in federal spending have done little to help the instrument business. Appropriations increases have gone primarily into the one third of total R&D spending that is for defense, an area whose R&D efforts give essentially no support to the purchase of smaller-scale instrumentation.

Although it is difficult to come up with an exact total amount for government grants used for the purchase of instruments, it is evident that federal appropriations for research are increasing less quickly than in the past. Nonetheless, several tens of millions of dollars are slated specifically for the purchase of instruments. For instance, the Department of Energy has $5 million to spend on its instrumentation program each year. The University Research Initiative Program of the Department of Defense includes $25 million to be used only for the purchase of research instruments. In addition to shared instrument grants at about $32 million, the National Institutes of Health funds a $45 million program for the development of biomedical research apparatus. The chemistry division of the National Science Foundation hopes to spend nearly $18 million on instrumentation grants, $11 million of which is for undergraduate education. This money is becoming available slowly; some of the 1988 NSF proposals are just beginning to be funded in fiscal 1989. And authorized but not funded in the trade bill recently passed by Congress is $85 million for the upgrading of college and university research facilities (C&EN, Aug. 8, page 6).

Despite funding delays, economic ups and downs, and business dealings, some new technologies and innovations still manage to appear in analytical instruments. Recent developments have been in automation, data handling and analysis, and in the combining or "hyphenating" of techniques.

Most existing instrument lines show at least some growth, several being at or above the level of growth of the entire market. A general survey of the market suggests that all instrument lines have been helped by increased computerization and spreading application in growing industrial markets. Of 31 instrument types surveyed by Alpert & Sutcliffe, those based on molecular analysis constitute 69%, or $2.8 billion, of 1987 sales, and elemental analysis, 31%, or $1.3 billion in sales. Market share of various instrument lines differs geographically as do the dominant manufacturing centers.

Chromatography is the fastest-growing area, comprising 40%, or $1.5 billion, in 1987 world sales. Chromatographic methods are used extensively in industrial labs, which purchase about 70% of the devices made, for separation, purification, and analysis. One of the biggest words in all forms of chromatography is "biocompatibility." Biocompatible instruments are designed to have chemically inert, corrosion-resistant surfaces in contact with the biological samples.

The largest U.S. sales of individual instrument types go for high-performance liquid chromatography (HPLC) and gas chromatography (GC) instruments, with $276 million and $175 million in 1987 sales, respectively, the Alpert & Sutcliffe study shows. HPLC sales have grown at rates of at least 10% over the past few years, although the market is maturing domestically and currently is growing at about 8%. The higher-cost, but more efficient, HPLC technology has nevertheless caused sales of more standard liquid chromatographs (LC) to flatten.

Again, it is biotechnology and new drug development efforts that are expected to affect HPLC sales. Expectations are that large scaleups of fermentation and genetic engineering will lead to increased use of HPLC instruments. In addition, the developing market for on-line monitoring, process control, and quality control has been predicted to be as large as $90 million in sales. Millipore/Waters Chromatography, the third largest U.S. instrument company with sales of more than $200 million in 1987 and 1988, has introduced one of the first on-line HPLC systems for process control.

Gas chromatograph sales are growing at about the same rate as the instrument market. Some of the newest innovations in GC technology are the production of more instruments with high-efficiency, high-resolution capillaries and supercritical fluid capability. Despite having only a 3% share of the GC market, supercritical fluid chromatography (SFC) has attracted a great deal of attention since its introduction around 1985 and production of the first commercial instrument around 1986. SFC, which operates using a supercritical fluid as the mobile phase, bridges the gap between GC and HPLC. The use of these mobile phases allows for higher diffusion rates and lower viscosities than liquids, and a greater solvating power than gases.

Another area showing tremendous growth is ion chromatography (IC). From growth levels of 30% per year in the U.S. and similar levels worldwide, the rate is expected to drop slightly but remain high at 25%. IC's popularity has been enhanced through extending its applicability from inorganic systems to amino acids and other biological systems by the introduction of biocompatible instruments.

Mass spectrometry (MS) sales have been growing about 12% annually. Sales have always been high, especially since MS is the principal detector in a number of hyphenated techniques such as GC-MS, MS-MS, and LC-MS. GC-MS accounts for about 60% of MS sales since it is used widely in drug and environmental testing. Innovations in interface technology such as inductively coupled plasma/MS, SFC/MS, and thermospray or particle beam interfaces for LC-MS have both advanced the technology and expanded the interest in applications. Recent introductions of lower-cost MS instruments with automated sampling and computerized data analysis have added to the attractiveness of the technique for first time users.

Spectroscopy accounts for half of all instrument sales and is the largest overall category of instruments, the Alpert & Sutcliffe study shows. It can be broken down evenly into optical methods and electromagnetic, or nonoptical, spectroscopies. These categories include many individual high-cost items such as MS, nuclear magnetic resonance spectrometers, x-ray equipment, and electron microscopy and spectroscopy setups. Sales of spectroscopic instruments that are growing at or above the market rate include Fourier transform infrared (FTIR), Raman, NMR, plasma emission, and energy dispersive x-ray spectrometers. Others have matured and slowed down in growth, but may still hold a large share of the market.

FTIR spectrometers have been a popular instrument line for the past few years. Their sales last year amounted to $148 million. This area has had 20 to 30% growth per year in the U.S., but levels are now reaching a more moderate 12%. The U.S. led in development of the technology and, following the usual trends, then showed tremendous growth and led in sales. This spurt in growth is now occurring in other markets as the instrumentation is adopted for use. The Western Pacific market is increasing at 35 to 45% a year, aided by the introduction of instruments from overseas manufacturers such as the Japanese. The number of suppliers of FTIRs worldwide is large and, with tough competition, the cost per instrument has recently dropped below $20,000. This bodes ill for dispersive IR instruments, sales of which have decreased 8 to 10% because of competition with the faster, more sensitive, and computerized FT methods.

Most of the larger-growing instrument lines see the same general trends affecting the market, according to the Alpert & Sutcliffe report. Plasma emission spectrometers had the typical rapid growth after the recession characteristic of a young technique. Sales have now leveled off to about 11% growth, but remain strong as ICP devices continue to compete with the not-so-strong atomic absorption techniques. NMR spectrometer sales are growing because of new applications in biomedical research and based on more sophisticated experimental methods using increased computing power. Similarly, Raman spectroscopy, traditionally used in academic research, is gaining in acceptance in industrial R&D and quality control but is doing so from a small sales base. Materials research and surface analysis in a variety of industries keeps sale of the electron microscopic, electron spectroscopic, and x-ray techniques growing.

The future of analytical instrumentation does not appear to be without its new stars as there continue to be innovations and developments in existing technology. Among these are the introduction of FT Raman, IR dichroism, IR microscopy, and NMR imaging spectrometers. Hyphenated and automated apparatus are also appearing on the market more frequently. New analytical techniques like capillary electrophoresis, gel capillary electrophoresis, scanning tunneling microscopy for the imaging of conducting systems, atomic force microscopy for the imaging of biological systems, and other techniques for surface and materials analysis are already, or may soon be, appearing as commercialized instruments. And, if the chemical industry continues to do well in the next few years, so too will the sales of analytical instrumentation. □

NOVEMBER 28, 1988

CHEMICAL & ENGINEERING NEWS

PVC

House siding use helps push up polymer's demand
Page 15

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CHEMICAL & ENGINEERING NEWS

NOVEMBER 28, 1988

News of the Week

- **Canada's Prime Minister Brian Mulroney was returned to office last week, and, with a Conservative majority in the House of Commons, the way seems clear for approval of free trade agreement with the U.S.** **Page 4**
- **NSF will provide $2 million over five years for novel program to promote collaborations between mathematicians and molecular biologists.** **Page 5**
- **U.S. Patent & Trademark Office's automated patent system is set for first full production use in new PTO data center just opened.** **Page 5**
- **Paul Gassman, Regents Professor of Chemistry at the University of Minnesota, has been elected ACS's 1989 president-elect.** **Page 6**

Cover: Photo courtesy of the Vinyl Institute

Letters 2

Concentrates

Business 12
Government 18
Science/Technology 21

The Departments

ACS News 36
Meetings 45
Newscripts 60

News Focus

Four-year-old saga of Bhopal litigation has moved nearer to an end, with Indian Supreme Court considering an appeals court decision calling for Union Carbide to pay interim damages to victims. **Page 7**

Government

Plans for future federal regulatory actions are detailed in agenda published in *Federal Register;* proposed revisions to Superfund's guiding regulatory framework have been issued by EPA. **Page 19**

Science

New lead-strontium-copper oxides superconductors have unusual features, contain PbO-Cu-PbO sandwich not seen before; Elias J. Corey of Harvard University is honored with symposium. **Page 22**

Education

Oregon Graduate Center expects to double faculty and quadruple students over next five to eight years. **Page 26**

Technology

New family of silicone release coatings cuts production costs for pressure-sensitive adhesive labels and tapes. **Page 31**

Books

"The Art of Scientific Writing" by Ebel, Bliefert, and Russey thoroughly covers topic, uses examples drawn from chemistry. **Page 34**

Awards

ACS award winners: Parshall, Rapoport, Regnier, Schrader, Schreiber, Somorjai, Stewart, Szarek, and Taylor. **Page 39**

Business

Production capacity for polyvinyl chloride is increasing, owing to a rapid rise in PVC applications, such as siding and other architectural products. **Page 15**

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LETTERS

Fluoridation of water

SIR: I must say that the article on fluoridation by Bette Hileman (C&EN, Aug. 1, page 26) implies rather different conclusions than I have drawn, based on careful study of the data and the issues.

The author has accurately reported that the fluoridation of community water supplies has engendered highly emotional responses from a minority of the population and broad-based support from health professionals. Support has been based on the ability of fluoride to increase the resistance of teeth to decay, thus helping to prevent disease. There is abundant scientific evidence for the beneficial effects of fluoride dating back half a century and confirmed in numerous studies including very recent reports. With the improvements in oral health that have occurred, the amount of disease prevented by fluoridated drinking water today may be less than 50 years ago. Still, the fact remains that those who have had lifelong access to fluoridated drinking water experience less dental decay, on average, than those who have not had such access.

Historically, opposition to fluoridation has been based largely on constitutional issues and on a myriad of purported health concerns. The constitutional issues have been fully dealt with by a number of state supreme courts that have upheld fluoridation as legal and appropriate. The U.S. Supreme Court on several occasions has determined that there is no basis for a review of the state court decisions.

In terms of purported health concerns, there is much evidence to indicate that there is no scientific basis for concern and no credible evidence of harm that would justify abandonment of fluoridation as a valued public health measure. As Surgeon General, I have directed two scientific reviews of the effect of naturally occurring fluorides on human health. Although these studies were not targeted at the practice of community water fluoridation per se, it is clear from the evidence that at the level of fluoride that is recommended for community water systems, dental decay is significantly reduced and no deleterious side effects are experienced.

Hileman may have intended to present the issues in a neutral light, but she misses her mark. Little attention is accorded the massive amount of evidence that has documented the effectiveness and safety of fluoridation and thus the great public health benefits that have occurred at little cost to the taxpayer. Much emphasis is placed on allegations of harm, all of which have been substantively dealt with by scientific experts, the courts, and regulatory bodies at the state and national levels. The use of boldface headings, accusatory language such as "Health risks: more questions than answers" and "Promoters' style has fueled fluoridation controversy," and the use of photos of apparently crippled individuals from other parts of the world as an example of what fluoride could ostensibly cause in the U.S. fall below the standards of credibility and veracity and in no way could be viewed as objective journalism.

It is rare that there is total consensus about any issue that is brought before the public or, indeed, in science. However, general public debate is not the most appropriate forum for pursuing scientific truth. Scientific research and review by qualified experts can point to the best choices of health-promotion and disease-prevention measures, based on existing evidence. For methodological and other reasons such as random variation, the results of scientific investigations can never be expected to be 100% consistent. Yet with water fluoridation, the beneficial results have been markedly significant, consistent, and reproducible.

For my part, I will continue to support community water fluoridation and recommend it to communities as an effective public health measure. I will continue to encourage scientific inquiry into the role of fluorides in human health. And I will continue to review dispassionately the scientific evidence relevant to these considerations. I would encourage others to do the same.

C. Everett Koop, M.D.
Surgeon General

Editor's note: Surgeon General Koop's comments about the credibility, veracity, and objectivity of the C&EN article should be assessed in the light of questions raised by numerous scientifically qualified individuals and organizations about the fluoridation of drinking water supplies. These questions are largely concerned with present understanding of the impacts of fluoride on human health and with ambiguities over the efficacy of fluoridation as a tooth decay preventative in children.

The discussion of health risks in the C&EN article covers only topics that have been examined in detail by credible and responsible scientific organizations such as the National Academy of Sciences and the National Research Council of Canada. Like the C&EN article, reports from these groups do not advocate that fluoridation be discontin-

Demand for Architectural Products Helps Boost PVC Capacity

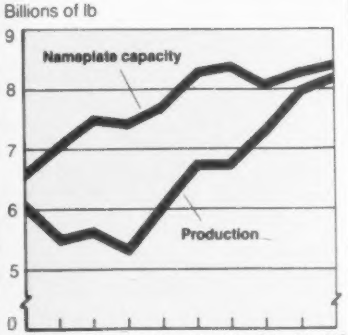
Rapid rise in use of vinyl products, including vinyl siding for home remodeling, sparks debottlenecking efforts and construction of new plants

Bruce F. Greek, C&EN Houston

Strong demand in architectural applications this year has led polyvinyl chloride producers to fully use all in-place plant capacity. Demand for vinyl siding and accessories has grown as a result of new developments in forming, coloring, and resistance to weathering, sparking overall growth in PVC consumption. The surge in new plant capacity coming on stream this year has shaped the outlook for PVC production during 1989, which could match or exceed the more than 5% increase forecast for 1988.

As of the end of August, consumption of PVC in vinyl siding and related products reached more than 470 million lb, up 12% over the same period of 1987. That consumption, however, is a distant second to the 2.2 billion lb made into pipe, one of the several end uses detailed by the Committee on Resin Statistics of the Society of the Plastics Industry. For all of 1988, siding and related products alone are expected to require more than 700 million lb of PVC, or about 9% of forecast U.S. consumption of more than 7.8 billion lb.

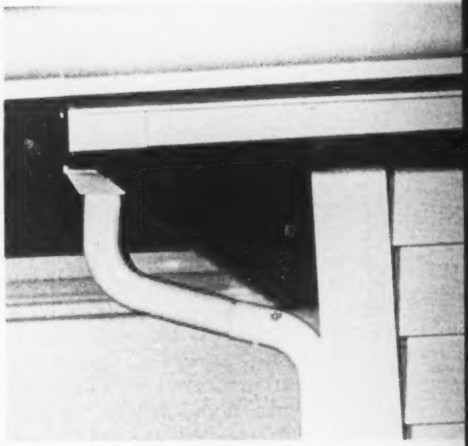
PVC capacity use soars after several-year lag



ª Production estimate based on January through August data. **Sources:** C&EN estimates, Committee on Resin Statistics of the Society of the Plastics Industry

Most of the vinyl siding consumed goes on existing houses as part of repairs or maintenance to substitute for painting. Little of the vinyl siding is believed to be used on new houses or on commercial buildings. Rapidly rising selling prices of both new and existing houses in most parts of the country have led many home owners to spend more fixing up their houses instead of trying to move up to larger houses. Quality improvement in vinyl siding and smaller price increases than in aluminum siding are cited by industry sources as the major reasons for the rapid growth in demand.

Vinyl siding and PVC producers are unsure that more vinyl siding could be sold if more were available. Competition from other uses of PVC, some of which are growing faster than siding but from a smaller base, may be limiting siding output. For example, vinyl flooring made by calendering, such as conventional vinyl tile, consumed 11% more PVC through August this year than last year. Consumption of PVC in molded bottles was up more than 32%, to almost 150 million lb, and in film and sheet for packaging it was up more than 21%, to almost 225 million lb through August, according to SPI. Other PVC uses during the first eight months of 1988 generally have shown gains, except in pipe, wire and cable coverings, and some small uses.



Gutters, downspouts are a major part of PVC architectural products market

Serious limitations to PVC production during the first half of this year caused hard decisions on which specification resin would be produced to meet which end use. Shortfalls in output, compared with what might have been sold, resulted from limits on polymerization capacity, limited availability of monomer (vinyl chloride), and, in turn, limited availability of precursor (ethylene dichloride). Consequently, producers of PVC may have shifted output toward the higher-value resin forms and reduced output of resins with lower selling prices, such as pipe grades.

Pipe consumption of PVC indeed has slipped this year. After a good start, pipe demand turned down in March and slid more during the second quarter, as housing and commercial construction declined or made very few gains. At the same time, inventories of finished pipe were reduced. More recently, the decline in pipe demand for PVC has slowed, with the August decline slightly under 1% compared with August 1987. No significant recovery is expected in the remainder of this year. For the year, pipe consumption will total 3.2 billion to 3.3 billion lb, down about 3.5% from 1987 consumption. Even so, pipe will account for more than 40% of total U.S. consumption of PVC.

A variety of causes have been suggested for the slowdown in demand for PVC in pipe. One is that a small shift from multifamily housing to more single-family units has reduced use of smaller-diameter PVC pipe in areas such as drain, waste, and vent piping. Another proposed cause relates to the relatively rapid increase in prices of PVC pipe resins. Current prices are 42 to 45 cents per lb, up from well below 30 cents per lb two years ago. The price increase has made ductile iron pipe less expensive in large diameter sizes, which are widely used in city water distribution systems. Easier handling and lower shipping costs, because of its lighter weight, offset the higher cost of PVC pipe to some degree, however.

Although demand has increased rapidly for PVC in vinyl siding and related products, such as window components, PVC use in packaging is also growing fast. Film and some sheet forms used in packaging required close to 300 million lb of PVC last year; this year these packaging uses may total close to 360 million lb, or nearly half the use in siding. Use in bottles for a variety of household products is growing even faster, but from a smaller base. In 1988, molded bottles will consume about 225 million lb of PVC, up from last year's consumption of 160 million lb.

Total PVC consumption in the U.S. this year of 7.8 billion to 8.0 billion lb would represent a 3% gain from 1987. Another 400 million to 500 million lb of PVC will be exported. The sum of uses will require a total production of 8.2 billion to 8.5 billion lb, up about 5% from slightly less than 8.0 billion lb produced in 1987. Because of the relatively large amount of new PVC and vinyl chloride capacity that either has come on stream in 1988 or is yet to be started up and because of additional capacity to be made available in 1989 (early enough to contribute significantly to production during the rest of 1989), production of PVC in 1989 could increase at least 500 million lb, or more than 6%.

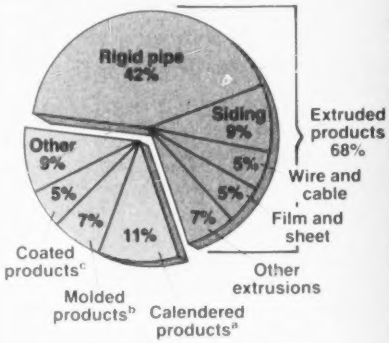
However, the outlook for PVC production and consumption faces several uncertainties. For example, a decline in housing and commercial construction in the next year could dampen demand for pipe resins even more than during this year. Demand for PVC pipe used in water systems involving government agency contracts would hold up better, because the longer lead and construction times of these projects would partly offset effects of any downturn. A downturn, however, likely would not dampen production of PVC as much as it would sales, since both producers and consumers may build inventories from the current low levels of about 10 days' production. Bringing inventories up to 30 days of production, the desired level on a historical basis, could add 5% to annual production.

Exports pose uncertainties in the outlook for consumption and production of PVC, although exports increased more than 9% during the first eight months of this year, to an annualized rate of about 480 million lb. That rate is 65% above the 1985 level of 292 million lb (the lowest level of the decade), according to SPI. Heightened business activity around the world, especially in the Far East, contributes to the currently strong export picture. But the outlook for exports remains cloudy, partly owing to economic uncertainties, but also because of uncertainty about when new capacity to make PVC will come on stream in other parts of the world, especially in the Far East.

Exports of PVC, of course, would be much larger than they now are, or have been, if the polymer were exported at the levels that PVC precursors are exported. In 1987, for example, more than 840 million lb of vinyl chloride were exported. Between 750 million and 800 million lb of PVC likely was made from the exported material. Additionally, more than 950 million lb of ethylene dichloride was exported in 1987. Between 500 million and 550 million lb of PVC could have been made from that ethylene dichloride. (Not all ethylene dichloride is used to make vinyl chloride and PVC; other uses may take 10% or more of the total in some export markets.)

To meet demand for PVC this spring, plants of all 13 producers were run at or above effective capacity. Similarly, the plants of eight vinyl chloride producers, many of whom make PVC, also were run full out to supply the monomer to fill both domestic and export demand. Most ethylene dichloride, vinyl chloride, and PVC plants have been expanded or are being expanded. Some of the capacity gained is in relatively small debottlenecking projects, but other projects are much larger, including some world-scale units on which construction has not yet begun but that are well into the planning and site selection stages. Because of numerous plant expansion projects in other PVC precursor chemicals and small expansions that are never announced, actual nameplate capacities for each of the

Rigid pipe and siding account for half of U.S. PVC use



1988 sales and captive use[d] = 7.9 billion lb

a Includes flooring and textile. b Includes bottles and pipe and tubing fittings. c Includes flooring, textile and paper coatings, protective coatings, and adhesives. d C&EN estimate; excludes exports. **Source:** Ernst & Whinney for the Committee on Resin Statistics of the Society of the Plastics Industry.

compounds are difficult to determine. Some vinyl chloride plants have been expanded this year just as increased supplies of the monomer were needed to meet demand from PVC expansions. PVC expansions probably have been insufficient to meet demand, however, indicated by increased selling prices, only part of which can be attributed to the sizable increases in prices for ethylene and chlorine, the basic raw materials for PVC.

Early this year, in-place capacity to make vinyl chloride totaled about 8.7 billion lb. Work already was under way on several sizable expansions that added more that 500 million lb to capacity through the early summer. Other expansions completed this fall and still others scheduled to be completed by the end of the year will bring capacity at the beginning of 1989 to about 9.5 billion lb. So these expansions will have added almost 10% to vinyl chloride capacity in a year's time, a considerable amount of new capacity to have come on stream within a year.

In the most recent large vinyl chloride capacity addition, Dow Chemical added 240 million lb of capacity at the end of the third quarter to a plant in Plaquemine, La. That expansion is part of an ongoing program that will eventually add another 210 million lb of capacity to plants at Plaquemine and Freeport, Tex., giving Dow a nameplate capacity of about 2.2 billion lb in 1990.

Other producers, such as B. F. Goodrich Chemical, Borden Chemical, Georgia Gulf, and Vista Chemical, have added vinyl chloride capacity through incremental expansions this year. Expansions of vinyl chloride capacity normally entail addition to ethylene dichloride capacity as well. For some producers who have uses for ethylene dichloride other than making vinyl chloride, or who sell ethylene dichloride, capacity expansions may be larger than expected from the vinyl chloride expansion announcements.

Another major round of vinyl chloride expansion is beginning. In addition to debottlenecking projects, such as Dow's program and those of other vinyl chloride producers, Occidental Chemical is in a joint venture with Marubeni Corp. of Japan to build a 1 billion lb-per-year vinyl chloride unit on the Gulf Coast, with construction scheduled to start in the second quarter of 1989 and completion slated for late 1990. Occidental also has plans under way to increase capacity of an existing plant from 900 million lb to 1.1 billion lb next year. Formosa Plastics will add about 400 million lb to its capacity as it replaces an old plant with a new unit during the next two years. Other vinyl chloride producers may have projects under way, but they have not been announced publicly.

However, vinyl chloride producers were unable to fully utilize their capacity additions earlier this year. Preliminary data from the U.S. International Trade Commission show that ethylene dichloride production in this year's second quarter declined about 25 million lb from the first quarter to 3.32 billion lb at a time when demand pressure was especially high.

One reason behind this decline, and the subsequent decline in vinyl chloride and PVC output, was the limited availability of raw material ethylene. During the second quarter, several large steam crackers were shut down for varying lengths of time because of accidents or maintenance. Available ethylene went to uses that provided the largest returns, such as polyethylene manufacture. Therefore, ethylene dichloride and ethylene oxide production sometimes took secondary positions in terms of access to ethylene supplies.

Despite difficulties in getting raw materials, PVC producers are expanding capacity. Earlier this month, for example, Shintech Inc. completed a 500 million lb-per-year expansion at its Freeport, Tex., plant, bringing total capacity there to 1.5 billion lb. This expansion was completed more quickly than the original schedule, which called for half the capacity to be on stream late this year, with the rest coming next year. As this year's expansion was completed, another 500 million lb expansion for completion in 1990 was approved by Shintech's board of directors, according to Chihiro Kanagawa, president and chief executive officer.

Exports of PVC precursors outstrip exports of PVC

Millions of lb	Ethylene dichloride	Vinyl chloride	Polyvinyl chloride
1979	1137	1117	322
1980	612	872	465
1981	617	836	436
1982	796	927	566
1983	970	685	534
1984	759	1027	379
1985	973	1015	292
1986	583	1490	370
1987	953	844	430
1988[a]	930	630	480

[a] C&EN estimates based on January through August 1988 data. Sources: Department of Commerce, Committee on Resin Statistics of the Society of the Plastics Industry

Many other PVC producers are adding capacity in smaller quantities. Prior to announcement of plans for the 1 billion lb-per-year vinyl chloride plant with Marubeni, Occidental had disclosed debottlenecking of its plants during 1987–88 and additional expansions to bring the company's capacity to about 2 billion lb of PVC per year. Other major producers, including Goodrich, Borden, CertainTeed, Georgia Gulf, Formosa, and Vista, have expansions either recently completed or under way for completion soon.

The various PVC capacity additions this year will total nearly 1 billion lb. At the beginning of 1989, in-place capacity will be about 9.4 billion lb for PVC, an increase of 12% for the year. Expansions during 1989 are forecast to be considerably less than in this year, probably ranging from 300 million to 400 million lb. Another 1 billion lb or more of capacity could be available in 1990.

If the PVC capacity can be operated as fully as is needed to meet sales and captive use requirements during 1989, production of PVC could increase 7 to 9%, considerably higher than the 5% increase in 1988 and nearly comparable to the growth in 1987. That could raise PVC production to about 8.9 billion lb in 1989. An economic downturn could foil such a gain, but most industry observers expect 1989 growth of at least half that rate, even if more output goes to exports. □

DECEMBER 5, 1988

CHEMICAL & ENGINEERING NEWS

1989 Pittsburgh
Conference program
Page 47

Community Relations

Chemical companies
reach out to fight
poor image Page 13

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CHEMICAL & ENGINEERING NEWS

DECEMBER 5, 1988

News of the Week

- **The technical community is optimistic that President-elect Bush will lift the level of science advice in his Administration.** Page 4
- **The first major U.S. patent in high-temperature superconductivity will be issued to MIT.** Page 5
- **Six leaders of U.S. environmental groups meet with President-elect Bush to urge action on pressing environmental issues.** Page 5
- **G. D. Searle says it will ask for a new trial in the Cu-7 contraceptive case as a result of allegations of jury misconduct.** Page 6
- **Synthesis of gold-carbon species results from calculations based on relativity theory.** Page 6

Cover: Dow Chemical researcher works with high school student in community program designed to stimulate interest in science careers

Letters 2

Concentrates

Business 7
Government 22
Science/Technology 30

The Departments

New Products 29
ACS Focus 44
ACS News 62
Newscripts 78

Government

High indoor concentrations of volatile organic chemicals are found in EPA survey of 10 buildings. **Page 23**

Technology

Course on safe handling of genetically engineered organisms is latest effort of German chemical technology group DECHEMA to increase emphasis on biotechnology. **Page 31**

Education

Plight of physics literacy in high schools is underscored in study conducted by American Association of Physics Teachers. **Page 35**

Books

In **"Beyond the Laboratory: Scientists as Political Activists,"** Peter J. Kuznick ascribes political awakening to Great Depression, when scientific expansion was halted. **Page 36**

Meetings

1989 Pittsburgh Conference miniprogram includes symposium sessions, registration and other information. **Page 47**

Awards

ACS winners: Johnson, Allinger, Denmark, Fox, Knowles, Meinwald, Overman, Streitwieser, Trost, and Whitesides. **Page 55**

Business

More chemical company community relations programs must deal with community fears about the presence of chemical plants and possible harmful effects. **Page 13**

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LETTERS

Human side of science

SIR: There will no doubt be criticism of Rudy Baum's review (C&EN, Oct. 31, page 42) of Sheldon Glashow's "Interactions: A Journey Through the Mind of a Particle Physicist and the Matter of This World."

We chemists, despite our protests to the contrary, are an emotionally neutral group. We allow the human side of science to be revealed only in metered, piecemeal fashion. What Baum has presented to us is the whole picture: the science, the presentation, and the author, as revealed by the author's words. Compare this style with the endless droning on scientific details that some reviewers find so comforting.

Baum's article should be made required reading for all C&EN book reviewers.

David E. Hughes
Alternate Councilor
ACS Norwich Section
Norwich, N.Y.

Chemistry of Stradivarius

SIR: I would like to respond to one of the letters prompted by my article on the chemistry of Stradivarius. In his comments (C&EN, Oct. 17, page 3), W. L. Stanley assigned more guilt and responsibility to me than I can possibly bear.

My special report (C&EN, May 23, page 24) does not say anywhere that chitin was used by the Cremona violin makers, who have already been credited with too many deep insights. The use of partially deacetylated chitin for acoustical purposes was clearly my own invention as it was described in two articles written for the premier journal of violin making [*J. Violin Soc. Amer.*, **6**(2), 53 (1980) and **6**(3), 19 (1983)].

More serious is the notion, also advanced by Stanley, that I may be held responsible for some violin varnishes that look like oatmeal cookies when, in fact, my own varnish has the appealing look of a candied apple. I must ruefully admit that I did advocate the use of Mount St. Helen's volcanic ash as a filler in my 1980 article. However, it is my educated guess as an oatmeal consumer that the brown pozzolana ash, which was first recommended by J. Chipura in *Strad* magazine in 1984, may be the culprit involved. This clay-rich soil is inherently opaque, which may limit its uses to the larger and cheaper instruments.

Naturally, there are many valuable skills involved, but the current renaissance of violin making would be unthinkable without the vigorous participation of chemists and materials scientists. The apple remains the prerequisite of the apple pie.

Joseph Nagyvary
Professor
Texas A&M University

Politics and chemists

SIR: I was gratified by your coverage of Rep. George Brown's remarks at the ACS national meeting in Los Angeles on more political activity by chemists (C&EN, Oct. 3, page 10). I have been active in partisan politics for most of my adult life, and my greatest frustrations are experienced when talking to other chemists. Not only are scientists too shy about taking public stances on political issues, most are reluctant to get even minimally involved in elective politics.

Unfortunately, over the past 30 years or so, partisan politics have become anathema to many professional people, not just scientists. The reasons for this can be discussed, perhaps even understood, but some important implications of this attitude should be pointed out.

Many scientists of my acquaintance who have registered to vote (and far too many have not) list themselves as "unaffiliated" and think that makes them "independent." On the contrary, in most states these voters are completely dependent on activists in the two major parties to choose the nominees for political office at every level, from county sheriff to President of the U.S. I thus have little patience with educated people who complain about the quality of the candidates when they have made no effort to help choose those candidates.

I urge my fellow ACS members to get involved in the full electoral process, including state and local politics. State legislators, county commissioners, and others are frequently confronted with technical issues that they do not understand. There is no better way to get an elected official's attention after the election than to have worked on his or her campaign. Moreover, you might be pleasantly surprised to learn that your credibility has been enhanced, even if your candidate is defeated! At the very least, you will gain a better appreciation of the political realities of the technological issues you care about.

It is usually argued that a scientist's objectivity would be compromised by such activity. This could be true in a few

Survey Finds High Indoor Levels Of Volatile Organic Chemicals

EPA monitoring study focuses attention on current need for increased research funding to better understand indoor air quality problems

Lois R. Ember, C&EN Washington

People are exposed to much higher levels of dangerous air pollutants in office buildings, schools, hospitals, and nursing homes than outdoors, even in heavily industrialized cities, the Environmental Protection Agency says. But by legislative fluke, neither EPA nor any other agency is charged with regulating indoor air quality.

A five-year, $850,000 study by EPA, the first of its kind, found more than 500 volatile organic compounds (VOCs), most only once, in a survey of 10 buildings. Indoor concentrations for all compounds except benzene exceeded outdoor levels, clearly indicating indoor sources. Aliphatic hydrocarbons were the compounds found most frequently, followed by aromatic hydrocarbons and chlorinated hydrocarbons.

New buildings were found to have very high concentrations of aromatic and aliphatic hydrocarbons immediately after completion. Over the next several months, concentrations dropped rapidly, sometimes by an order of magnitude. Occasionally it took up to a year for indoor concentrations to drop to the concentration of the same pollutants outdoors. Recognizing this, Scandinavian countries require 100% outdoor air as makeup air for the first six months of a building's existence.

Though EPA's study supports the need for the Scandinavian practice, the agency has not set such a standard. As Lance A. Wallace of EPA's Office of Research & Development and the project officer on the 10-building monitoring study explains, "We have the data but we don't have the authority." Robert B. Axelrad, director of EPA's indoor air division, confirms this. "At this point, we don't believe we have any legislative authority to do that. We can't regulate under the Clean Air Act." The agency confines its efforts to regulating ambient air, which, in 1970, it defined as air external to buildings.

In the 10-building monitoring effort, EPA researchers tracked the VOCs to common items: building materials, cleaning solvents, furnishings, and pesticides. Latex caulk, carpet adhesive, latex paint, telephone cable, carpeting, and particle board were some of the highest emitters of VOCs. With the thrust to tighter, more energy efficient buildings, these compounds can build up to very high concentrations.

Most people spend nearly 90% of their time indoors, and for this reason are potentially at greater risk of developing health problems from breathing indoor air than from outdoor air. And those spending the most time indoors—the very young, the very old, and the chronically ill—are potentially the most susceptible to such adverse effects as headaches, depression, fatigue, irri-

Myriad organic compounds typically found indoors

Aromatic hydrocarbons
Benzene
Diethylbenzenes
Dimethylethylbenzenes
Ethylbenzene
Ethylmethylbenzenes
Methylnaphthalenes
1-Propylbenzene
Naphthalene
Propylmethylbenzenes
Styrene
Toluene
Trimethylbenzenes
Xylenes

Halogenated hydrocarbons
Chloroform
Dichlorobenzenes
Dichloromethane
Tetrachloroethylene
1,1,1-Trichloroethane
Trichloroethylene
Trichlorofluoromethane

Alcohols
2-Butyloctanol
1-Dodecanol
2-Ethyl-1-hexanol
1-Hexanol

Esters
Ethyl acetate
1-Hexyl butanoate

Aliphatics
Cyclohexane
Decane
Dodecane
2,4-Dimethylhexane
1,3-Dimethylcyclopentane
Eicosane
Heptane
Hexane
Methylcyclohexane
4-Methyldecane
2-Methylheptane
2-Methylhexane
3-Methylhexane
3-Methylnonane
2-Methylpentane
3-Methylpentane
Nonane
Octane
Pentadecane
Pentane
Tetradecane
Tridecane
Undecane

Aldehydes
Decanal
Nonanal

Miscellaneous
Acetic acid
Acetone
Dimethylphenols
Ethylene oxide

Source: Environmental Protection Agency

tability, allergylike symptoms, heart disease, and cancer.

In some new buildings xylenes and decane, chemicals associated with the so-called "sick building syndrome," were found in concentrations 100 times greater than outdoor levels. According to Axelrad, the sick building syndrome is "a collection of symptoms for which a cause has not been identified." The potential causes include chemicals (very low levels of VOCs) as well as biological agents such as bacteria and fungi. Many people in sick buildings, including EPA's own headquarters building, claim to have become chemically sensitive, though there is no clinically acceptable test for chemical sensitivity. Many cite allergylike symptoms, which seems to implicate biological agents.

Congress began to focus its concern about indoor air quality in 1982 when it mandated that EPA define the problem by monitoring air quality in buildings. Because EPA failed to budget for a monitoring effort, Congress, by line item, appropriated about $500,000 for the 10-building study for the years 1982 and 1983. In 1984 and 1985, Congress upped the line item sum to $2 million. This larger amount, however, also covered other related research efforts such as looking at kerosene heaters and gas stoves as pollutant sources. By 1985, EPA began to put money for indoor air quality research into its budget request.

So far, Congress has pegged all resources for research and none for regulation. Neither Congress nor the Administration has shown any inclination to regulate the indoor air quality of public buildings. And, in fact, no one in EPA familiar with the problem feels that enough is known at this time to introduce a command-control regime for indoor air.

Additional studies are needed on the health risks to people exposed to low levels of a mixture of chemicals, EPA's Wallace says. As Axelrad explains, "We need more research to decide what's safe." Some of the VOCs found in buildings are cancer-causing compounds. EPA doesn't recognize a safe level for a carcinogen. But it does set action levels for some indoor pollutants. Radon is one example.

Until 1982, EPA had little if any expertise in the area of indoor air quality. Most of the expertise in building and ventilation systems rested with the Department of Energy. With the 1970s oil crisis, energy efficiency became the watchword, and buildings became more airtight. With less air exchange, DOE recognized that pollutants could build up indoors and so the agency began to study the problem. DOE, however, has no authority to regulate in this area.

EPA is now looking for its appropriate role. Axelrad, who directs the policy side of the indoor air program, says EPA can continue to research the problem, and develop and disseminate information to the public as it becomes available. Or the agency can take a command-control approach—that is, regulate.

At the moment EPA is opting for the former role for several reasons. Many in the agency feel that substantially more funding must go into researching the health risks and mitigation strategies for the mix of chemicals found indoors. Standard setting on a pollutant-by-pollutant basis, as has been done for ambient air, is not an effective way to improve indoor air quality, they claim. Putting out information to give the public guidance is a more meaningful approach now, they say, than trying to issue fruitless regulations.

So along with the release of the 10-building study, the agency distributed two booklets. One, a "Directory of State Indoor Air Contacts," is a 129-page listing of state agency contacts for 16 indoor air-related issues. The second, a 32-page booklet entitled "The Inside Story—A Guide to Indoor Air Quality," describes the sources of pollutants, how to control them, and the health risks associated with them.

This latter booklet offers three strategies for taming the problem: source control, improved ventilation, and the use of air cleaners. EPA has "done little on the health effects of very low levels of pollutants and on mitigation technologies," Axelrad says. "There is certainly a need for a significantly expanded program to evaluate air-cleaning technologies and other mitigation strategies," he adds.

David Hawkins, senior attorney with the Natural Resources Defense Fund and former EPA administrator for air programs, says EPA can begin to do several things immediately. "First, the agency can without delay begin to deliberate with authorities that set building standards. Also the agency can begin advocating within the Administration for more resources," he says.

"EPA would have a strong case for setting standards for new buildings," Hawkins claims. And if President-elect George Bush's campaign promises mean anything, EPA probably will be getting higher levels of funding under his Administration, which means more money for indoor air programs, he reasons. "Bush set himself up to deliver in environmental areas. Whatever the flexible freeze means, it must apply in those areas of the campaign he stressed and the environmental area is one such area," Hawkins says.

EPA is monitoring the activities of ASHRAE, the American Society of Heating, Refrigeration & Air Conditioning Engineers. ASHRAE, a standard-setting organization that sets guidelines for building contractors, has in the past issued a standard that would give every person 5 cu ft of fresh air per minute. The organization is now revising this code to 15 cu ft per minute per person.

Axelrad says this revision is "a comfort standard, not a safety standard. But it is the only thing available that the building community has in the way of guidance."

The agency is looking at ventilation strategies and at indicator levels such as total VOCs as ways of approaching the indoor air quality problem. But EPA has neither the authority nor the desire to set ventilation or VOC standards.

A staff member on Rep. James H. Scheuer's Subcommittee on Health & the Environment of the Energy & Commerce Committee applauds EPA's monitoring study. "It's the first time any regulatory agency has gone out to look at public buildings in any methodical way. EPA's study raises new concerns about the level of VOCs that seem to be released in new office buildings," he says.

Rep. Scheuer (D.-N.Y.), who held hearings this year on indoor air

Indoor concentrations of volatile organics in new buildings greater than outdoor levels

	Aromatic hydrocarbons			Aliphatic hydrocarbons			Chlorinated hydrocarbons			Oxygenated hydrocarbons			Total		
Nanograms per liter	Indoor	Outdoor	Indoor/ outdoor ratio	Indoor	Outdoor	Indoor/ outdoor ratio	Indoor	Outdoor	Indoor/ outdoor ratio	Indoor	Outdoor	Indoor/ outdoor ratio	Indoor	Outdoor	Indoor/ outdoor ratio
New hospital															
34 weeks old	18	5.4	3.3	7.0	nd	nc	8.1	3.7	2.2	1.3	nd	nc	34	9.1	3.7
48 weeks old	11	5.1	2.2	4.7	nd	nc	6.0	5.3	1.1	nd	nd	nc	21	10	2.1
1½ years old	26	6.2	4.2	5.1	nd	nc	26	3.2	8.1	nd	nd	nc	57	9.4	6.1
New office building															
1 week old	270	16	17	810	nd	nc	13	1	13	nd	nd	nc	1100	17	65
14 weeks old	54	13	4.2	98	nd	nc	56	3	19	8.5	nd	nc	220	16	14
New nursing home															
4 weeks old	93	8.5	11	173	nd	nc	9.9	2.8	3.5	9.6	nd	nc	286	11	26
23 weeks old	22	17	1.3	7.3	nd	nc	3.9	2.5	1.6	1.2	nd	nc	34	20	1.7

Note: Building ages are approximate. nd = not detectable (below quantifiable limit), nc = not calculated. **Source:** Environmental Protection Agency

quality, says, "Indoor air will be a high priority for my committee next year." His aide says that "with a new Administration, we might be able to make some progress in this area."

Another House member active in promoting indoor air quality programs is Rhode Island Republican Rep. Claudine Schneider. EPA made certain that she received copies of the two booklets and the 10-building monitoring study. However, at press time Michael Totten, the legislative aide covering the issue for the Representative, had "not had a chance to review the material."

As Scheuer indicates, the issue is not going to die. Come early next year, EPA will present Congress with the indoor air quality report mandated by Superfund. Under the revised Superfund law, the report was to be coordinated by EPA but was to outline governmentwide activities in the area of indoor air quality.

The deadline for submitting this report to Congress was October 1988, but the press of other business has kept EPA behind schedule. At the moment the report is undergoing internal review.

As it now stands the report is in three volumes. The first outlines all federal indoor air activities. The second enumerates assessment and control technologies. And the third documents research needs. According to EPA sources, the agency is also putting together a primer on indoor air quality that will be submitted as a separate volume.

While EPA was coordinating the report to Congress, the agency and the National Institute for Occupational Safety & Health (NIOSH) were busy tackling the sick building syndrome within the federal complex. Workers at the fairly new Madison Building of the Library of Congress have complained of ill health effects, which they believe are caused by microbial aerosols.

Harriet A. Burge, associate research scientist at the University of Michigan Medical School, under contract to NIOSH, focused her monitoring effort on biological aerosols—fungus, mold, bacteria—not on volatile organic chemicals. She sampled the building for three days in the summer and found normal microbial levels. But she says the conditions were not ideal for finding high levels of biological aerosols, if they are present. "I didn't detect anything I would consider contamination," she says, "but you can't interpret my data set until winter samples are taken." Because of the presence of books, circulating air in winter is humidified. That being the case, she has said that if abnormal levels are to be found, their possible source might be air washers in the air handling units. Burge believes that next year NIOSH will be conducting a written survey and DOE will be taking ventilation samples.

At EPA headquarters, VOCs were the focus of another monitoring effort. One of the buildings was undergoing renovation. Some EPA employees became acutely distressed upon entering these renovated quarters. A monitoring study found hundreds of VOCs, but at extremely low levels. Because new carpeting had been laid, scientists looked for 4-phenylcyclohexene. Not surprisingly, this odorous compound, the product of the reaction of styrene and butadiene found in the backing of new carpeting, was detected at about 1 ppb.

None of the chemicals was found at a high enough level to be fingered as the culprit. But the health effects noted by some workers could have been caused by the mixture of chemicals found. An early 1980s study determined that people breathing a mixture of 22 compounds, all present at low levels, were unable to concentrate and suffered memory loss. The total concentration of the 22 compounds was 5000 ng per L, a VOC concentration found in some so-called sick buildings. EPA is now replicating this study.

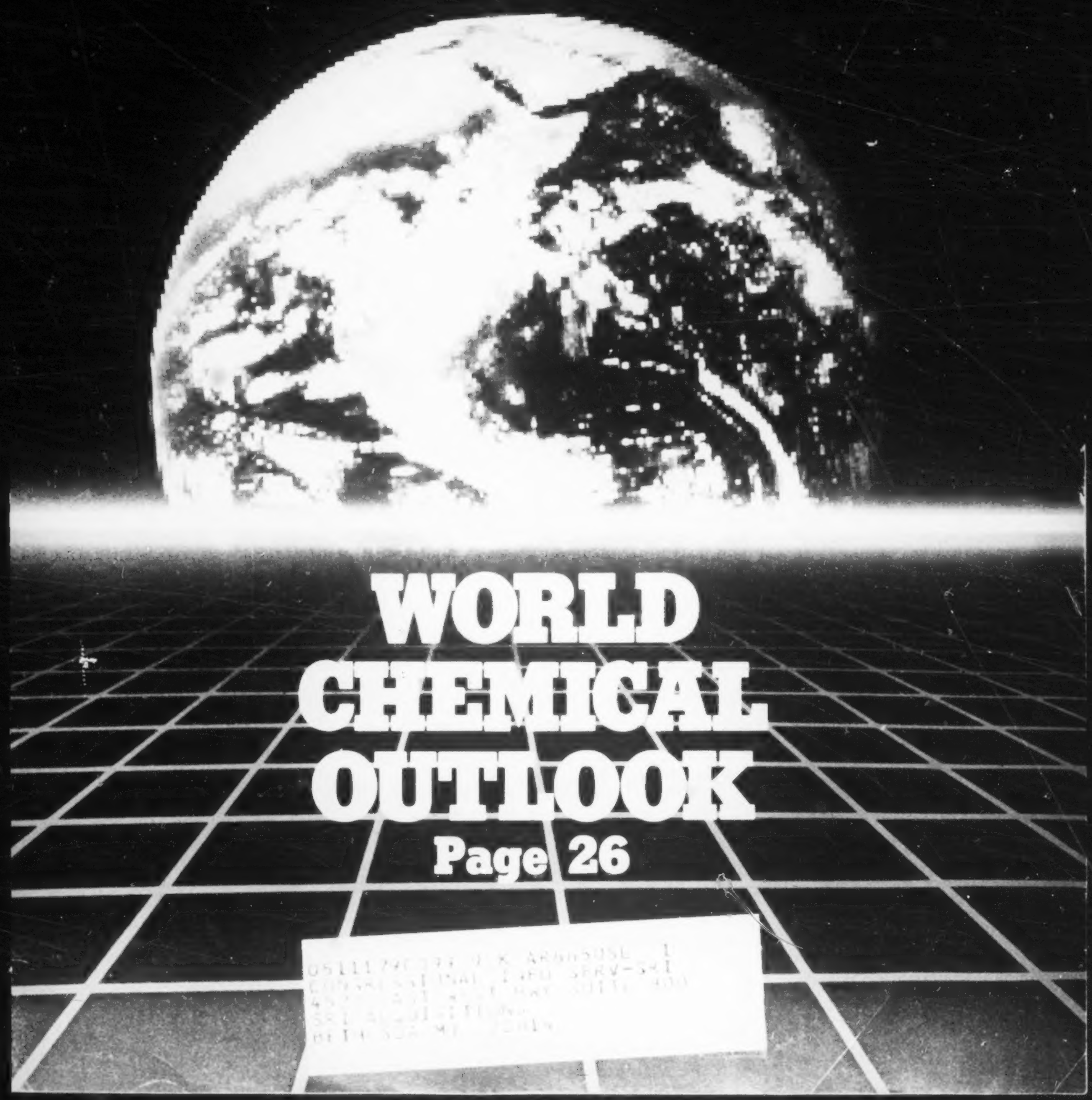
Because EPA's headquarters monitoring effort was inconclusive, the agency is planning to conduct a written survey this January. All workers in EPA's three headquarters buildings will be asked to describe their health symptoms.

The agency is on the upward slope of a steep learning curve. As Wallace explains, "EPA has never dealt with a sick building." □

CALENDAR OF EVENTS
Scientific meetings
Page 53

DECEMBER 12, 1988

CHEMICAL & ENGINEERING NEWS



WORLD CHEMICAL OUTLOOK

Page 26

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CHEMICAL & ENGINEERING NEWS

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News of the Week

- **Dow Chemical and Pfizer plan to exchange shares of their stock for new financial products called unbundled stock units in effort to boost their earnings per share.** Page 4
- **International group of scientists, environmental leaders, and policy makers calls for developing strategies now to deal with the coming effects of greenhouse warming.** Page 5
- **Science and technology centers to be established by NSF at 11 universities will tackle complex problems.** Page 6
- **New director general of UNESCO is striving to restructure and reinvigorate the troubled United Nations organization.** Page 6

Cover: Imtek Imagineering/Masterfile

Letters 2

Concentrates
Business 7
Government 16
Science/Technology 22

The Departments
ACS Comment 47
ACS News 49
Newscripts 72

Business

Facing a revenue shortfall, Cytogen increases its marketing and licensing operations to obtain funds for expensive clinical trials of its biotechnology-based products. **Page 13**

Virtually odor-free hydrocarbon solvents for the paints and coatings industry are introduced by Shell Chemical. **Page 14**

Government

"Blueprint" presented to President-elect Bush by environmental coalition lists over 700 recommendations for management of environmental problems. **Page 19**

Japan has pulled even with U.S. in scientific and technological resources, NSF report shows. **Page 20**

Technology

Chromatography columns that mimic cell membranes show promise in separating and purifying proteins and other biochemical entities. **Page 23**

Low-cost cleanup of toxic petrochemicals from soil and groundwater is offered by innovative "steam-cleaning" process. **Page 24**

Books

Drama behind discovery of the endorphin enkephalin makes interesting reading for half of book, but remainder loses focus. **Page 45**

Meetings

C&EN's semiannual calendar of meetings and events lists those of interest to chemists, chemical engineers. **Page 53**

WORLD CHEMICAL OUTLOOK

With demand for chemicals strong and supplies generally tight, chemical companies throughout the industrialized world expect to chalk up another year of rising sales and profits in 1989 as they continue to run their plants at close to design limits. **Page 26**

Chemical & Engineering News

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LETTERS

CHEMICAL SAFETY

1,1,1-Trichloroethane

SIR: A recent explosion during welding on a tank containing 1,1,1-trichloroethane illustrates the fact that this "safer" solvent is, in fact, flammable and can form explosive mixtures with air, though it has no recorded flash point. Wrightson and Santon [*IChE Loss. Prev. Bull.*, **83**, 21 (1988)] give a full description of the incident in a 1050 cubic meter tank holding 70 metric tons of inhibited solvent under nitrogen to exclude moisture. Owing to gas leaks in the roof, the nitrogen supply system had been switched to manual operation, and insufficient gas had been fed into the tank after a previous removal of 1150 metric tons to displace the air drawn in. When arc welding repairs were started, the resulting explosion separated the tank roof from the walls for two thirds of the 36-meter circumference. Another explosion had been recorded when the end of an "empty" 200-L drum was being cut with an oxy-acetylene torch. Limits of flammability for 1,1,1-trichloroethane are narrow at 8.0 to 10.5% at 25 °C, with an autoignition temperature of 500 °C.

There seems to be an unfortunate tendency in many safety reference sources to describe partially chlorinated hydrocarbons for which no flash points are determinable by standard tests (because they are difficult to ignite), as nonflammable. Other examples of solvents of this type are dichloromethane (calculated flash point −9 °C, limits 12 to 19%, autoignition temperature 605 °C) and trichloroethylene (flash point 32 °C, wide limits 12.5 to 90%, autoignition temperature 410 °C). All three will ignite if the vapor temperature and ignition energy or temperature are sufficient. The same is true for bromomethane (limits 13.5 to 14.5%), formerly used to extinguish fires.

L. Bretherick
Bridport, Dorset, U.K.

Refocusing general chemistry

SIR: I was interested in Ward Worthy's report on the symposium on refocusing general chemistry held at the ACS meeting in Los Angeles (C&EN, Oct. 17, page 25). I did participate in this symposium and found it a useful forum in which to express and formulate my ideas on general chemistry and also to learn those of others. In addition to the points mentioned in Worthy's report, I found special interest expressed there in persistent errors propagated in current introductory texts such as the fiction that dissolved ammonia occurs in dilute aqueous solutions as ammonia molecules, the uncritical use of valence shell electron pair (VSEPR) theory in spite of its well-known conceptual inadequacies, and the common misrepresentation through oversimplification of equilibria in aqueous solutions, a particularly egregious example of which was given by Stephen Hawkes in his formal talk. I think all concerned would like to see such error eliminated or at least minimized. Yet the current record suggests that that desire is not likely to be satisfied so long as new texts depend heavily on those of the previous generation for much of their standard material. It would seem that a special effort is required to eliminate or minimize this way of perpetuating error in introductory textbooks.

An important point of general interest concerning the role of high school chemistry arose during the open forum that wrapped up the symposium. It was pointed out that the need for incorporating more descriptive chemistry into the college-level introductory chemistry course could be attributed, in part at least, to the paucity of such material in the high school courses. It was felt that the driving force for many high school instructors was to give their students a leg up in competing on the college level. As a result, the high school courses tend to emulate the introductory college courses. In this light, it was wondered whether any changes in the introductory college course would not soon be undermined by similar changes in the high school courses?

Hawkes deserves special commendation for his successful organization of this stimulating symposium.

Thomas R. Tuttle Jr.
Professor of Chemistry
Brandeis University

Nuclear power

SIR: The Government Concentrates page (C&EN, Oct. 24, page 15) carried an item entitled "Voters to decide on environmental issues." The item listed several environmental issues, but also included a comment about a Massachusetts referendum in which "voters will be asked to stop the commercial generation of nuclear power as of July 4, 1989."

Come on, C&EN! You should know—as all the rest of us know—that the antinuclear activists are not environmentalists. A sincere and realistic environmentalist supports nuclear power because it is cleaner and more environmentally ac-

"Blueprint" Details Environmental Challenges Faced by New President

Document comprises over 700 recommendations on global warming, ozone depletion, waste disposal, public-land stewardship, other issues

In an unprecedented effort called "Blueprint for the Environment," 30 major U.S. environmental groups have banded together to offer the incoming Bush Administration more than 700 recommendations on how to manage near-crisis proportion environmental problems affecting the U.S. and the world.

According to Thomas B. Stoel Jr., a senior attorney at the Natural Resources Defense Council, President-elect George Bush "faces environmental problems that rank with nuclear war" in their ability to wreak havoc. High on the list of potential environmental disasters is alteration of Earth's climate, the so-called greenhouse effect.

"The crisis is so pressing and so forbidding," says Jay D. Hair, president of the National Wildlife Federation, "that the problems transcend political parties, indeed, even nations." But the saving grace, he says, is that the solutions to the problems are within grasp: "No new leaps in technological progress are needed." In addition, the coalition believes that many of the problems facing the U.S. can be dealt with through executive order. Few require Congressional action.

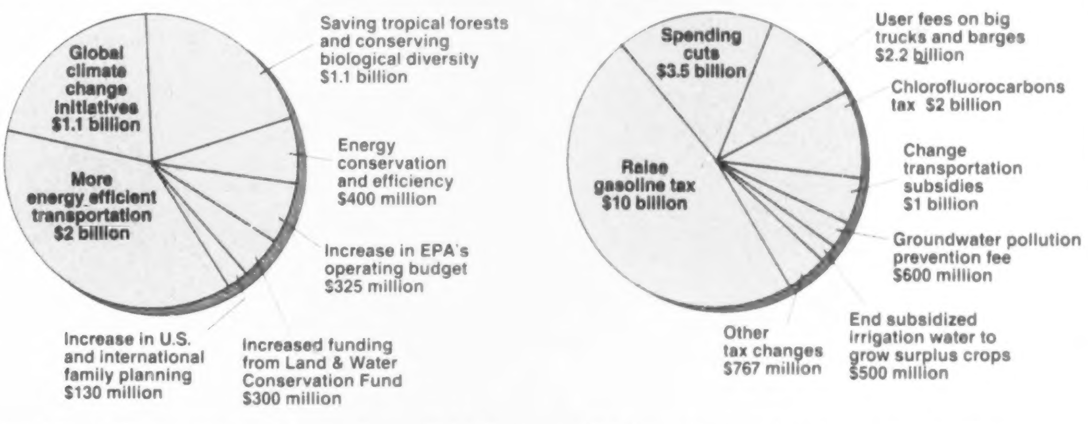
In a meeting with the President-elect, leaders of six U.S. environmental groups, all part of the coalition, presented their tome of recommendations in "Blueprint for the Environment" and urged Bush to exert control quickly and emphatically. Hair says the coalition initially will judge Bush's leadership by "the quality of key appointments" he makes to head the Energy and Interior departments and the Environmental Protection Agency.

The environmental leaders also say it is essential that Bush provide world leadership, especially when dealing with the issues of global warming and stratospheric ozone depletion. John H. Adams, executive director of NRDC, cites "global warming as the single most serious problem facing the world." He contends that President Bush's "reign will be judged on the success or failure of work on global warming."

As a group, the leaders believe that on domestic issues Bush has to come to grips with the issue of toxic substances. In that regard, the blueprint effort urges that the newly elected President call for swift renewal of the Clean Air Act and get a handle on the disposal of toxic waste and the cleanup of abandoned hazardous waste sites.

Environmental group calls for $5 billion boost in spending...

...and pickup of $21 billion through new taxes and savings



Total fiscal 1990 environmental spending = $5.4 billion

Total new taxes and savings = $20.6 billion

Source: Blueprint for the Environment

To curb pollution, "we must deal with the root cause: the generation of waste," says Hair. The blueprint recommends that Bush make waste reduction and recycling of waste a national priority. To do this, economic incentives and technical aid should be given to states and local governments.

And the environmental groups ask Bush to embrace the ethic of public-land stewardship, something, they feel, the Reagan Administration lacked. Public lands must be managed on a sound ecological basis; that is a given. But the environmental coalition also asks Bush to direct his Interior and Agriculture secretaries to ensure that lease or sale of resources belonging to the public be done "at full and fair market value," says the president of the National Audubon Society, Peter A. A. Berle.

According to Berle, "The key to a lot of what happens to the domestic environment is based on sound energy policy." Among the blueprint recommendations is improved energy efficiency, particularly the achievement of 45 miles per gal for the U.S. auto fleet by the year 2000. Another is to stress the development of renewable energy technologies, especially solar photovoltaic systems.

The blueprint coalition believes that Bush could demonstrate his support for enhanced environmental protection in two ways. First, elevate EPA to a Cabinet-level department. And second, increase EPA's operating fiscal 1990 budget 20%.

The shadows cast by the burgeoning deficit are long. And members of Bush's transition team say that expecting an increase in the agency's budget is wishful thinking. However, a Capitol Hill source familiar with environmental matters says that "Bush's folks are seriously considering" raising EPA to Cabinet level. As this source sees it, "That move would establish him as an environmentalist and would not hurt industry that much."

The blueprint effort counters the deficit argument with some budget proposals of its own. It says that $5.4 billion is needed for essential new environmental thrusts, including an additional $325 million for EPA and $1.1 billion for global climate change initiatives. But, it claims that through judicious spending cuts and increases in some taxes, $20.6 billion can be raised in fiscal 1990. According to this scheme, essential environmental programs can be funded and the federal deficit can be reduced by $15.2 billion.

Most of the increased revenue would come from taxes on ozone-depleting substances, gasoline tax increases, and users fees on large trucks and barges. The blueprint effort suggests an increase of 10 cents per gal in the gasoline tax. The Capitol Hill source says, "That's a bad idea. If you really want it to work you have to slap on a 50-cent or dollar per gal tax."

Basically the blueprint effort highlights environmental goals and recommends traditional means of achieving them. It calls for the rapid renewal of the Clean Air Act, including legislation to control acid rain. And it recommends tax increases, such as the one for gasoline, as means for promoting energy efficiency and paying for new environmental thrusts.

Not all major environmental groups are in harmony with these traditional approaches. "The problems are getting bigger, the solutions need to get better," Environmental Defense Fund executive director Frederic D. Krupp explains. His group was more comfortable working with Sen. Timothy E. Wirth (D.-Colo.) and Sen. John Heinz (R.-Pa.) on "Project 88." This effort resulted in 36 recommendations that "emphasize market-based incentives and solution-oriented approaches," Krupp says. "We're certain that the way to make progress [in stemming pollution] is to use the free market to steer the economy in the right direction," he adds.

The upshot is that Bush will be faced with another set of environmental recommendations to ponder. He was receptive to the environmental leaders who presented him with "Blueprint for the Environment." He smiled when Hair said, "Read my lips. Protect the environment." He answered, "I will." But he never told them in concrete terms how he would.

Lois Ember

Japan even with U.S. in high-tech indicators

Japan-watching is the craze in U.S. industry and government today. In almost every high-tech indicator except chemical processing and aeronautical engineering, Japan has pulled even with or drawn ahead of the U.S. A study of the scientific and technological resources of Japan and the U.S. just issued by the National Science Foundation tells why.

The report does not assess the Japanese "threat." However, a reader can draw a few conclusions from its 69 pages of text, charts, and tables. Data cover such areas as industrial productivity, patent activity, research and development in industry, patterns of science education, trade in high-tech areas, trends in R&D expenditures, and a lot more.

In the report, prepared by NSF science resources analyst Maria Papadakis, a number of items seem to stand out:

- Japan's science and technology resources (commitment to spending and education, growth in proportion to gross national product) are now on a par with the U.S.
- The relationship of R&D to GNP is about the same for both countries: 2.7 to 2.8%.
- Industrial research accounts for 69% of all research in Japan and the percentage seems to be growing. The U.S. ratio of government/industry research funding is about 50-50.
- Industrial R&D is 98% self-funded in Japan, 65% in the U.S. (with U.S. government providing the other 35%).
- Defense accounts for only 1% of Japan's R&D budget. In the U.S. it's 30%.
- Japan has about a third of the number of scientists as the U.S. does, but has slightly more engineers per 10,000 of the labor force than has the U.S.—187 to 183.
- Japan's share of world scientific literature is 7%, versus 39% for the U.S. But Japan's share of patents granted in the U.S. grew from 4% in 1970 to 19% in 1986.
- Between 1965 and 1985, the U.S. share of world exports in high-tech goods fell from 28% to 24%, while Japan's share rose from 7% to 19%.

Priorities list of Japan's research leaders

- Preventive measures for cancer metastasis.
- Elucidation of the biological cause and development of cancer cells.
- Development of technologies for major earthquake forecasting.
- Measures for controlling the growth of cancer cells.
- Clarification of growth mechanism of cancer cells.
- Storage and disposal of high-level radioactive solid wastes.
- Automatic protocol conversions to facilitate information flows between communications networks.
- Establishment of global integrated services digital network with automatic domestic access.
- Application of computer-aided design technology to design logic large-scale integration semiconductors of 1 million gates or more.
- Advanced software verification technology for rapid development of error-free, large software systems.
- Introduction of fast breeder reactors and establishment of complete nuclear fuel cycle facilities.
- Widespread use of antivirus agents for treatment of viral diseases.
- Industrial application of superconducting materials with T_c (transition temperature) higher than 77 K.
- Methodologies for analysis of protein structures so as to predict their functions.
- Technologies for designing primary protein structures to fulfill specific functions.

Source: Delphi Survey conducted by Japan Science & Technology Agency

Japan's world export share rose as U.S.'s slipped

	Japan		U.S.	
% share of world export market	**1975**	**1985**	**1975**	**1985**
Aircraft and parts	0.3%	0.4%	61.9%	50.9%
Industrial inorganic chemicals	6.4	4.2	18.4	20.7
Radio and TV receiving equipment	46.3	78.2	6.5	0.6
Office and computing machines	9.2	17.7	31.3	33.1
Electrical machinery and equipment	8.7	18.4	21.2	21.9
Communications equipment	14.9	37.0	24.4	16.1
Professional and scientific instruments	15.3	30.0	19.6	16.9
Drugs	2.0	2.7	13.6	18.4
Plastic materials, synthetics	12.0	9.6	12.0	13.2
Engines and turbines	8.7	17.7	25.9	29.4
Agricultural chemicals	12.0	3.2	24.1	30.7
All products	11.6	19.4	24.5	24.2

Source: National Science Foundation

- Japan is becoming an exporter of technical know-how. Its percentage of receipts-to-payments for technology licenses increased from 14% in 1970 to 30% in 1985. But it still is paying record licensing royalties of $1.3 billion (1985) for foreign technology.
- Japan's productivity increased 68% between 1977 and 1986, whereas the U.S. increase was 26% during the same period.

According to the report, Japan has taken three important turns in its science and technology policy during the past four years. It has shifted its research focus toward fundamental research, reformed some of the more "constraining" aspects of its R&D system, and decided to participate more fully in the international scientific community. All this was beginning to happen before negotiations began for the science and technology exchange agreement between the U.S. and Japan that was completed last June.

The shift in focus sprang from the technical community's realization that future growth and the fulfillment of national goals would have to derive from more indigenous scientific research. The U.S. could no longer provide the model, the Japanese concluded. Biotechnology, the software and hardware of information science, and energy-related research are sectors tabbed for emphasis in government and industrial research. But basic research will be stressed across the board, with universities, government agencies, and corporations all cooperating—or learning how to cooperate—to set priorities.

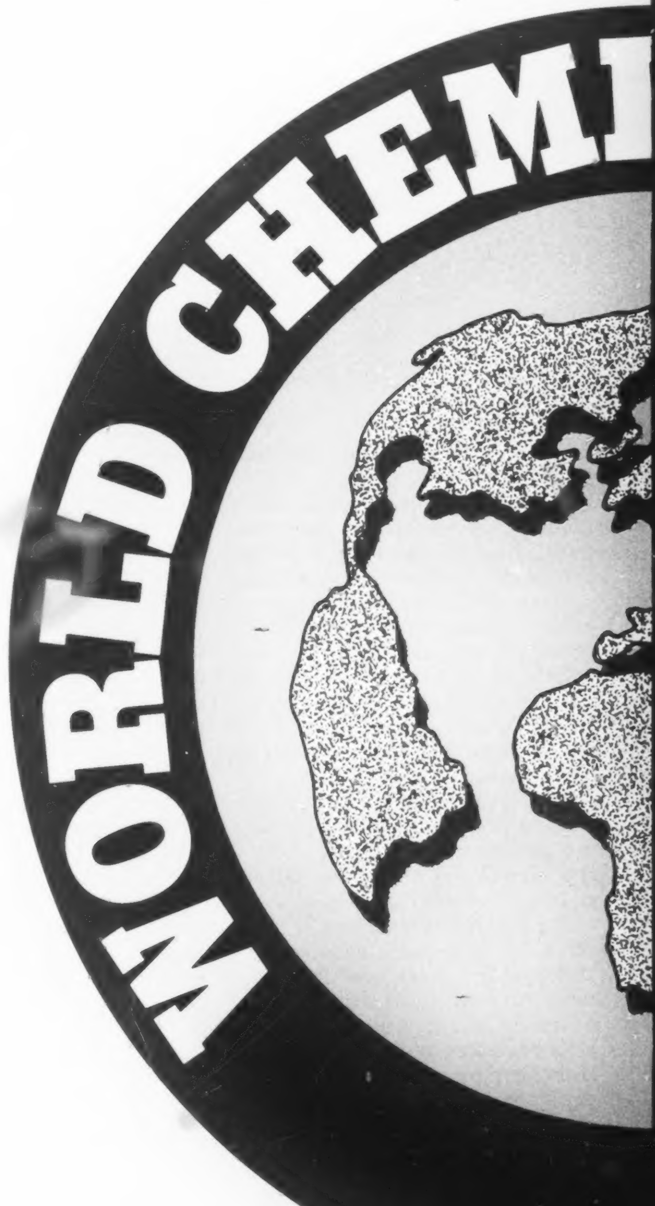
The structural reforms relate to the shifts in focus. The government's role in research is declining, and to effect more efficient spending, the focus is on limiting the life of new research programs to no more than a decade. Additionally, the Japanese Science & Technology Agency has been given a stronger coordinating role. Educational reforms aimed at training young people to think more creatively and independently are being emphasized, as is promoting more vigorous university-industry-government cooperation in research.

In the international sphere, Japan for the past few years has said it wished to reciprocate for all that it had received from Western science and technology. Shortages of spacious housing, the language barrier, and lack of interest by Westerners in doing research in Japan has inhibited any quick progress. But the country is gearing up to address those problems.

One issue that invites reflection by American policy makers is what Papadakis cites as the declining role of the Japanese government in research, from an annual growth rate of 6% during the 1970s to about 3% between 1980 and 1985. As it is, government research accounts for only about 20% of the total in Japan, with industry accounting for the rest.

"Thus," she says, "for the 1980–85 period, it appears that Japanese industry is rising to the challenge of continued increases in Japan's total R&D and basic research. Although the performance of R&D in Japan historically has been compartmentalized, as reforms are made throughout the R&D system, the ability of the Japanese to improve the efficient [use] of their research funds may be increased." She says the compartments are breaking down. There are now collaborative projects among sectors, industrial funding of academic research, and new ways to leverage research funds among sectors.

Wil Lepkowski



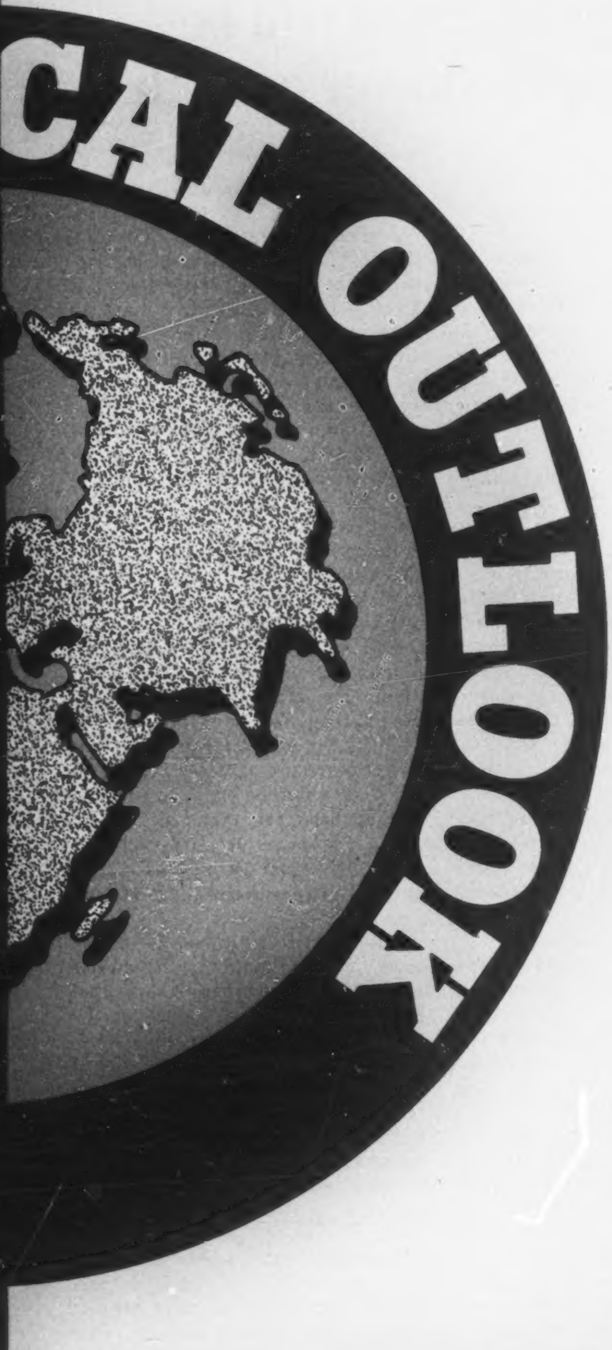
Chemical company executives in all the major industrialized nations of the noncommunist world are in happy harmony this year's end as they sing the praises of business conditions in their industry.

The tidings sound similarly glad whether they come from North America, Western Europe, or the Far East—which, perhaps, attests to the increasing interdependence, integration, and globalization of the world's chemical operations.

Business just about everywhere has rarely been brisker. Plants frequently are operating full out to take care of customers' orders. A seller's market provides chemical marketers the untypical privilege of marking up their prices, even as a glut in world crude oil supplies has forced down the cost of petrochemical feedstocks. Chemical organizations, meanwhile, remain trim and efficient following the massive restructuring during the mid-1980s that has drastically revamped the industry. The upshot: The industry's profits have been surging worldwide.

Few people in the industry expect growth in sales and earnings to continue next year at the same pace. In fact, that probably would be physically impossible, considering how tight supplies of basic chemicals are now. And economists, by and large, are convinced that the rate of economic expansion is likely to falter at least a bit during the next 12 months in most of the industrialized world. But the industry is moving into 1989 propelled by strong momentum and seems confident that it can cap the current decade with its seventh year in a row of higher sales and operating profits.

So for the present, fears that the siren song of high demand and heady prosperity will lure the industry again into a reckless round of plant buildup—with the inevitable result of glutted markets and cutthroat competition—are being put aside for the 1990s. Meanwhile, too, there is nothing like a strong cash flow to distract attention from workaday problems like increasing safety and environmental regulation, potential competition from developing countries, or basically maturing markets and product lines.



United States 28

Foreign Trade 31

Western Europe 34

Japan 38

Canada 41

U.S.S.R./
Eastern Europe 43

Chemical business will be brisk despite slower growth

United States

Hard-pressed to fill customers' orders, producers are reaping the rewards of a seller's market

David M. Kiefer, C&EN Washington

As 1988 began, executives of the U.S. chemical industry recognized that 1987 would be a hard act to follow. Business remained excellent, to be sure. Many plants were running close to capacity. Demand was strong, both in domestic and foreign markets. Selling prices were rising. And profits for the year just past had surged. Altogether, 1987 had been a stunning performance.

But there also had been many clouds on the economic horizon. Growth seemed to be faltering in several major markets. Fears were widespread that consumer confidence had been severely shaken by the collapse of stock values on Wall Street the previous October. The overall U.S. economy looked more than a bit unstable.

As it turned out, however, these fears were largely groundless. Economic growth during the past year has continued at a much faster pace than most business analysts had deemed likely 12 months ago.

Now, if the crystal balls of economic seers are to be believed, the U.S. economy will eke out another year of economic growth in 1989. And that is very good news indeed for U.S. chemical producers.

This year has been easily the best of the current six-year business expansion. Domestic demand for chemical products has seemed almost insatiable throughout 1988. Overseas markets have been even more buoyant, thanks to the competitive advantage bestowed by a weak U.S. dollar. Consequently, production of industrial chemicals, plastics, and synthetic fibers now is about 4% higher than it was late last year. For 1988 as a whole, output will be about 6 to 7% higher than in 1987.

That's not quite a match for the increase of almost 10% that the industry chalked up last year, but it's better than in most recent years. And demand for chemicals remains so strong that output would have expanded even higher this year if the industry had more plant capacity available. Earlier in the 1980s, demand was much softer and producers of basic chemicals, plastics, and synthetic fibers seemed confronted with several maturing markets. Much capacity was underutilized. Prices were depressed. And profit margins were unacceptably thin. So the chemical industry trimmed back its plant capacity.

For the past couple of years, however, the chemical industry has been running its remaining plants, especially those making plastics and the raw materials needed to produce them, just about full out. According to the Federal Reserve Board's rather theoretical data on capacity utilization, in the overall chemicals and allied products industry plants were pumping out product at 88% of capacity in this year's third quarter, up from 85% a year earlier and from just 68% at the low point during the 1982 recession. Operating rates have not been so favorable for the industry, in fact, for well over 30 years. The Federal Reserve Board figures, moreover, probably understate the situation.

For the second year, therefore, chemical producers have been reaping the benefits of a seller's market. They have been steadily marking up the prices of their products—as any consumer buying antifreeze this winter can well attest. On the average, industrial chemicals will be priced about 12% higher this year than in 1987, a year when prices, in turn, had been hiked about 4%. The rate by which prices are being raised, moreover, seems to be accelerating. Prices of industrial chemicals now are about 15 to 16% higher than last winter. Prices of plastics at present average about 20% more than a year ago. And the price of that key chemical commodity, ethylene, has much more than doubled during the past year or so.

On the other hand, producers of basic petrochemicals have been enjoying a potent break in the cost of their basic raw materials. In October, the price of crude oil was down 31% from 12 months earlier and the price of natural gas was up a mere 1%.

Higher prices, lower feedstock costs, and high plant operating rates are a heady combination, one that has been working wonders for the chemical industry's earnings statements. For companies in the core of the industry—producers of industrial chemicals and polymers—the opportunity to supply bulging demand at higher prices translates into a hefty increase in dollar sales of between 15 and 20% this year to about $115 billion (exclusive of sales of foreign subsidiaries). Earnings, in turn, are likely to be 50 to 60% higher for the year as a whole, soaring to an all-time high of nearly $11 billion. This year's gains are even better than last year's, when earnings climbed about 40% on a 12% increase in sales.

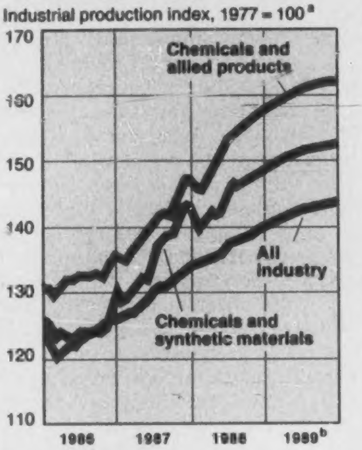
It's not just the core of the industry that is doing well, moreover. Pharmaceutical makers—a key segment of the overall chemicals and allied products industry—likewise have had a banner year. Several drug companies have benefited from the high rate with which they have been introducing new products, ones in many cases that command premium prices and were developed for treating chronic conditions over extended periods. A number of companies, too, like their colleagues in the basic chemicals sector, have restructured their operations in recent years to eliminate operations of marginal profitability and upgrade their manufacturing and marketing efficiency. Consequently, drug companies' sales probably will be up 10 to 12%, as net income climbs 50 to 60%.

Fertilizer companies, too, have enjoyed a turnaround in their business during the past year or so, after several relatively depressed years. With farm income rising, demand has been strong, export markets are even stronger, selling prices are up, ammonia and urea plants are running close to capacity, and profits are rebounding.

It has been a good year, as well, for the diverse assortment of companies that make up the specialty chemicals business, producers whose output ranges from adhesives to water treatment chemicals. Specialty firms that use petrochemical intermediates to formulate their own products have had a problem, however. If they lack a captive source, they have been faced with fast-rising raw materials costs. They, too, have been increasing their selling prices to compensate. But doing so has not always been easy, and, as a result, many specialty producers have been faced with a cost-price squeeze in the past year or so. Even so, sales are strong and profits are improving, if not at the same rate as in the basic chemical arena.

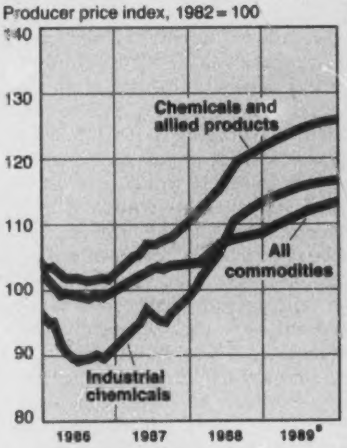
For the overall chemicals and allied products industry, therefore, output will be 8 to 9% higher than in 1987, sales are expected to rise 12 to 15%, and profits are likely to be up 40 to 50%.

With chemical production continuing to expand . . .



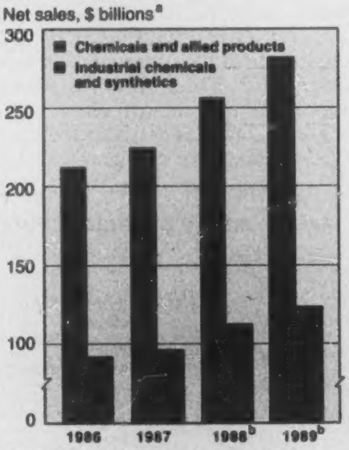
a Seasonally adjusted. b C&EN estimates.
Source: Federal Reserve Board

. . . and prices likely to be higher . . .



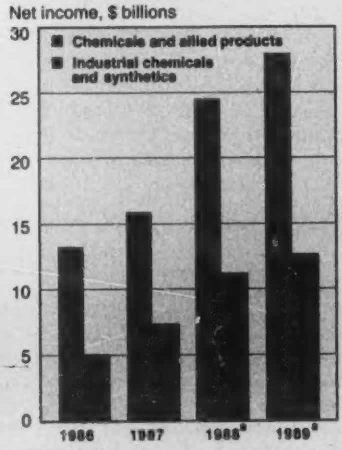
a C&EN estimates.
Source: Bureau of Labor Statistics

. . . sales will be strong again next year . . .



a Excludes sales of foreign subsidiaries. b C&EN estimates. Source: Bureau of the Census

. . . and chemical firms' profits will rise further



a C&EN estimates.
Source: Bureau of the Census

All in all, then, the chemical industry enters the new year riding on strong momentum. Industry executives are optimistic that a biblical seventh year of plenty lies ahead.

The current consensus of economic opinion pegs growth of the U.S. economy at about 2% for 1989, give or take a half percentage point or so. That's on the heels of a 4% increase in constant-dollar gross national product expected this year.

Economists generally welcome such a slowdown, moreover. With an unprecedented six years of expansion behind it, the nation's economy is running nearly as full out as is feasible without developing serious stresses. Continued rapid growth, economists fear, would only result in uncontrollable inflation and dangerously higher interest costs.

The chemical industry, too, probably would be hard put to expand its output for another year at the same rate as in the past two years. Even if the industry shows no further growth above current levels of production, its output during 1989 will be about 3% higher, on average, than this year. It probably will do better than that, though. If the U.S. economy pulls off a 2% growth rate during the year ahead, total production of industrial chemicals and synthetics is likely to climb 4 to 5%. Prices will continue to be firm to higher again, moreover, probably averaging 6 to 8% over this year's level. Sales, as a result, are likely to rise 10 to 12% and earnings will do at least as well.

Several key markets for chemicals bear watching, however. Housing is one. New housing starts have been falling from 1986's peak level of 1.8 million. Last year, housing starts totaled 1.62 million; this year they probably will reach no more than 1.4 million to 1.5 million. And next year, in the face of rising costs and higher mortgage interest rates, chances are that they will drop slightly further. That, in turn, will pinch demand for a variety of plastics, coatings, and fibers.

A slight decline in U.S. automobile production in 1989 also will not be surprising. Sales of cars and trucks in the U.S. probably will total about 15.6 million to 15.8 million units this year. Domestic production of new cars, meanwhile, will be about 7.1 million, practically unchanged from the year before.

Auto industry officials are generally sanguine about 1989. In fact, they recently announced plans to roll 14% more cars off their assembly lines in the first quarter of the new year than they made in the like period of 1988. But they may not maintain that pace for the whole year. Current forecasts from Detroit, in fact, foresee at least a slight dip in sales volume, to somewhere in the neighborhood of 10 million cars and 5 million trucks.

On the other hand, demand for fertilizer and other agricultural chemicals is expected to be good. Farm income is high at present and U.S. farmers are likely to sharply increase the acreage they have under cultivation to make up for crops lost in this year's drought and to take advantage of higher farm prices.

All told, moreover, consumer confidence remains high, according to recent surveys, and consumer income is rising as the ranks of employed workers continue to grow apace. That bodes well for many important outlets for chemicals. Slight gains are expected, for example, in demand for appliances, clothing and other textile products, and furniture. And with the dollar remaining weak against major foreign currencies, U.S.-made chemicals will retain their competitive advantage in foreign markets.

Thus, for the third straight year, chemical producers are likely to be more concerned with filling orders than drumming up new business. Therein lies one big concern of many industry observers. With demand pressing tightly against plant capacity, pressures are building to expand chemical facilities. So far, expansion has been largely limited to incremental additions at existing plants through process improvements and debottlenecking. These have allowed producers to satisfy customers' needs without heavy investments in new plants.

But already, construction is under way or plans have been announced for a few new petrochemical plants. That raises the specter, at least in the minds of some industry observers, of another glut of excess capacity and crumbling profits sometime in the 1990s if a business recession should crimp markets just as a bevy of new plants come on stream. □

Output will be up this year and next for nearly all major chemicals and polymers

	1986	1987	1988	1989
INORGANIC CHEMICALS				
Thousands of tons unless otherwise indicated				
Ammonia	14,487	16,095	16,900	17,750
Chlorine gas	10,442	11,019	11,400	11,600
Hydrochloric acid	2,392	2,869	2,900	3,000
Nitric acid	6,736	7,225	7,900	8,300
Oxygen, billions of cu ft	347	390	460	475
Phosphoric acid	9,578	10,685	11,700	12,300
Sodium hydroxide	10,405	11,486	11,900	12,100
Sulfuric acid	35,993	39,235	42,300	44,000
ORGANIC CHEMICALS				
Millions of lb unless otherwise indicated				
Acetic acid	2,728	3,246	3,300	3,350
Acetone	1,910	1,846	1,975	2,000
Acrylonitrile	2,182	2,452	2,550	2,650
Benzene,[a] millions of gal	1,362	1,576	1,640	1,680
Butadiene	2,546	2,931	3,100	3,175
Caprolactam	1,109	1,156	1,250	1,300
Cumene	3,745	4,105	4,500	4,700
Cyclohexane	2,070	2,276	2,300	2,350
Ethylene	32,859	34,951	36,500	38,500
Ethylene glycol	4,771	5,183	5,300	5,350
Formaldehyde	5,549	5,733	6,200	6,300
Methanol	7,205	7,537	6,800	7,300
Phenol	3,115	3,351	3,550	3,750
Phthalic anhydride	863	1,035	1,150	1,200
Propylene	16,522	19,019	19,600	20,500
Styrene	7,888	8,014	8,600	8,900
***o*-Xylene**	788	939	950	1,000
***p*-Xylene**	5,035	5,155	5,550	5,750
PLASTICS				
Millions of lb				
Polyethylene, high density	7,182	7,999	8,400	8,750
Polyethylene, low density	8,903	9,629	10,300	10,800
Polypropylene	5,812	6,647	7,400	7,900
Polystyrene	4,470	4,782	5,150	5,400
Polyvinyl chloride	7,256	7,971	8,450	8,800
SYNTHETIC FIBERS				
Millions of lb				
Acrylic and modacrylic	616	592	600	605
Nylon	2,515	2,690	2,725	2,775
Olefin and vinyon	1,393	1,494	1,620	1,725
Polyester	3,305	3,540	3,650	3,700

[a] Petroleum refiners only. **Sources:** Bureau of the Census, International Trade Commission, Society of the Plastics Industry's Committee on Resin Statistics, Textile Economics Bureau, C&EN estimates (for 1988 and 1989)

Foreign Trade

Surplus in U.S. chemical trade widens to new record

Weak dollar and strong overseas demand bring surge in exports, but U.S. chemical imports rise surprisingly also

Earl V. Anderson
C&EN Northeast News Bureau

It took eight years, but by the time this year's trade statistics are tallied, the U.S. chemical industry undoubtedly will have eclipsed the old record for its trade surplus of $12.1 billion that was set back in 1980.

Riding on a weaker U.S. dollar and strong overseas demand, chemical exports from the U.S. will increase about 23% this year to $32.5 billion. That's a level that they haven't even come close to before.

Meanwhile, chemical imports will probably weigh in at a record $20.1 billion, 24% higher than in 1987. Despite this surprisingly high increase, the U.S. chemical industry is likely to end the year with a trade surplus of about $12.4 billion.

This year's strong chemical import performance is surprising because conventional wisdom says that, when the U.S. dollar is weak versus major foreign currencies, U.S. exports become less expensive in the world marketplace and hence, more competitive against products made in other countries. Conversely, foreign products become more expensive in the U.S., so it is more difficult for them to compete against chemicals made at home.

There is no doubt that the U.S. dollar is significantly weaker against other currencies than it was, say, in 1985, when a U.S. dollar was worth an average 251 Japanese yen or 3.15 West German deutsche marks.

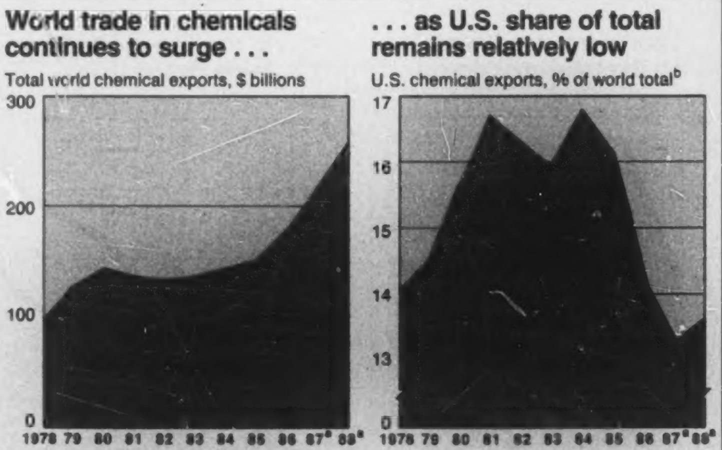
But the dollar's depreciation from its levels at the end of 1987 hasn't been nearly so significant as it has been in the past few years. In fact, the dollar staged a mini rally early in the year, recovering some lost ground before resuming its descent in the fourth quarter.

For instance, at the end of 1987, the dollar was worth 128 Japanese yen. By the end of last month, it had fallen, but only to 122 yen. Against the West German deutsche mark, it actually got stronger—1.735 deutsche marks at the end of November compared with 1.642 marks at the end of 1987. Still, at those dollar exchange rate levels, exports normally would be expected to increase faster than imports.

Overall, however, U.S. foreign trade is, in fact, complying with conventional wisdom. Total exports this year will reach almost $253 billion, up 27% over last year, whereas imports will advance only 8% to $440 billion (on a customs basis). This will shave about $33 billion off the well-publicized U.S. trade deficit, bringing it down to $120 billion.

Why isn't the same trend apparent in U.S. chemical trade? Despite the weaker dollar, the prices of chemical imports have been rising more slowly than those for chemical exports. Imports of chemicals, moreover, have been rising faster than exports on a volume basis as well.

Several explanations are possible. Some chemical trade observers say that U.S. companies are intentionally keeping export prices high to squeeze as much profit as they can out of their overseas shipments. Foreign companies shipping chemicals to the U.S., on the other hand, are



World trade in chemicals continues to surge . . .

Total world chemical exports, $ billions

. . . as U.S. share of total remains relatively low

U.S. chemical exports, % of world total[b]

a C&EN estimates. b Defined as U.S. chemical exports as percent of world chemical exports less U.S. chemical imports. Sources: United Nations, Organization for Economic Cooperation & Development, European Community, Japanese Ministry of International Trade & Industry

Organic chemicals, plastics, and drugs set pace for strong growth in U.S. chemical exports

$ Millions	U.S. chemical exports 1988[a]	1987	1986	1985	U.S. chemical imports 1988[a]	1987	1986	1985
Organic chemicals	$ 9,296	$ 7,550	$ 6,293	$ 6,012	$ 7,131	$ 5,408	$ 4,704	$ 4,576
Plastics and resins	6,455	5,492	4,301	3,777	2,191	1,987	1,837	1,631
Medicinals and pharmaceuticals	3,884	3,182	3,090	2,708	1,871	1,456	1,240	1,084
Inorganic chemicals	2,555	2,122	1,771	1,967	2,456	2,030	1,894	1,984
Fertilizers, manufactured	2,496	2,259	1,935	2,160	1,035	795	865	967
Pesticides and disinfectants	1,300	732	664	614	697	398	580	399
Radioactive materials	1,043	1,017	1,302	1,311	1,079	1,012	1,382	1,417
Flavors, perfumes, cosmetics, and toiletries	787	579	488	478	907	796	679	577
Pigments, paints, and varnishes	527	411	333	322	476	427	348	266
Cleaning and polishing materials	468	357	302	292	259	205	214	172
Dyeing, tanning, and coloring materials	319	217	174	139	726	621	487	352
Explosives and pyrotechnics	110	91	81	100	183	110	111	103
Miscellaneous	3,260	2,382	2,032	1,878	1,098	968	660	1,005
TOTAL	**$32,500**	**$26,381**	**$22,766**	**$21,759**	**$20,100**	**$16,213**	**$15,001**	**$14,533**

a C&EN estimates. Source: Bureau of the Census

holding prices down to maintain or increase market share.

Another possible reason is the difference between what is exported and what is imported. U.S. chemical companies export a lot of commodity chemicals, particularly ethylene derivatives, whose prices have increased rapidly because supplies are tight. Chemical imports tend to be intermediates, whose prices have not risen as much.

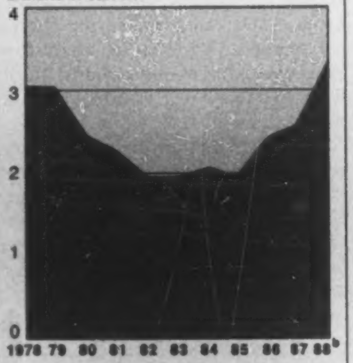
Chemical trade statistics seem to bear this out. U.S. exports of plastics and resins, which include several large-volume ethylene derivatives, will rise 18% this year to $6.5 billion. Plastics and resins imports, however, will increase only 10% to just over $2 billion.

But for organic chemicals, which include most of the intermediates, import growth is far outpacing export growth. Organics imports will hit $7.1 billion in 1988, 32% higher than last year, whereas exports of these products will increase only 23% to $9.3 billion.

In addition, many U.S. chemical plants have been operating at or near capacity this year. These capacity restraints, coupled with shortages of feedstock, also help explain why export volume hasn't grown even more than it has this year. U.S. producers often simply have

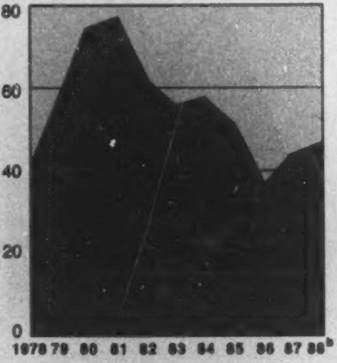
Volume of U.S. oil imports climbs sharply . . .

Billions of barrels[a]



. . . but lower price tags keep the total cost down

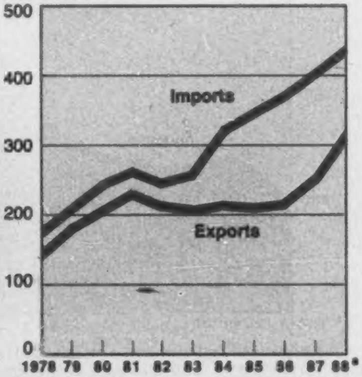
$ Billions[a]



a All petroleum products. b C&EN estimates.
Source: Bureau of the Census

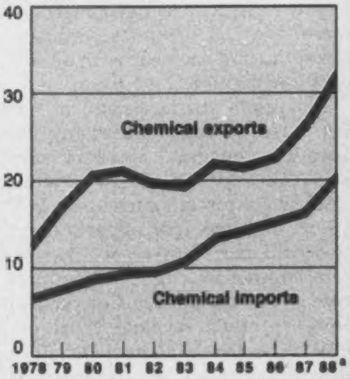
Strong rise in exports trims U.S. trade deficit . . .

$ Billions



. . . as surplus in chemical trade widens further

$ Billions



a C&EN estimates. Source: Bureau of the Census

Increased exports of chemicals and other manufactured goods help pare U.S. trade deficit

$ Billions	U.S. exports 1988[a]	1987	1986	1985	U.S. imports 1988[a]	1987	1986	1985
Chemicals	$ 32.5	$ 26.4	$ 22.8	$ 21.8	$ 20.1	$ 16.2	$ 15.0	$ 14.5
Machinery and transportation equipment	134.6	109.0	95.3	94.3	193.6	176.7	161.6	137.3
Other manufactured goods	46.6	36.8	30.5	29.3	132.0	119.1	105.5	95.0
Crude materials (inedible) other than fuels	25.4	20.4	17.3	16.9	13.6	11.5	10.4	10.4
Mineral fuels, lubricants, and related materials	8.1	7.6	8.1	10.0	42.9	44.5	37.3	53.9
Food and live animals	25.4	19.3	17.3	19.3	20.7	20.7	20.8	18.6
Beverages and tobacco	4.4	3.5	2.9	3.0	4.0	4.2	3.9	3.7
Animal and vegetable oils and fats	1.5	1.0	1.0	1.4	0.7	0.5	0.5	0.7
All other products	29.4	19.9	11.0	11.0	12.4	12.5	14.9	11.1
TOTAL	$320.0[b]	$252.9[b]	$217.3[b]	$213.1[b]	$440.0	$405.9	$370.0	$345.3

a C&EN estimates. b Includes re-exported imports (not included in individual product categories). Source: Bureau of the Census

not had enough product to satisfy domestic customers and at the same time push export sales.

Meanwhile, because strong economies tend to siphon in more imports, chemical import volume may have increased because of the surprisingly strong U.S. economy in 1988. And the huge foreign investments that recently have been made in the U.S. chemical industry may finally be having a "pull effect" on imports, as foreign companies ship products to their U.S. subsidiaries from their home countries.

Whatever the explanation for the relative strengths of chemical exports and imports, U.S. chemical traders aren't going to waste a lot of time analyzing the situation in a year of record trade surplus. Besides, too many other trade-related matters are commanding their attention.

For instance, they will have to learn to operate under the provisions of the new, huge, and extremely complicated trade bill that President Reagan signed in August. They will have to adjust to a new internationally harmonized system of tariffs that many U.S. trading partners already are using. Under the new trade bill, this harmonized system will replace existing U.S. tariff structures on Jan. 1.

Now that Prime Minister Brian Mulroney and his Progressive Conservatives have been returned to power in Canada, it's likely that Canada will approve the Canadian-U.S. free trade agreement. That means that U.S. chemical companies, like their Canadian counterparts, will have to learn to live with a new set of rules for trade between the two countries.

U.S. chemical companies also will have to learn to live with even more far-reaching new trade rules if 97 countries are able to reach a new trade agreement in the Uruguay round of multilateral trade negotiations. These negotiations, held under the auspices of the General Agreement on Tariffs & Trade (GATT), have been going on since 1986 and probably will last at least until 1990.

But for the past week, the experts who shape trade policy for the U.S. chemical industry have had their eyes focused on Montreal, where GATT negotiators met for a midterm review of progress in the trade talks. For the U.S. chemical industry, the prime concern is that U.S. negotiators don't give away too much in tariff concessions.

Under the new trade bill, the President has the authority, until 1993, to cut existing U.S. tariffs—generally, up to 50%. The chemical industry, however, wants tariff-cutting to be a low-priority exercise in the Uruguay round.

It doesn't want cuts in U.S. chemical tariffs made in exchange for tariff concessions for nonchemical sectors. Nor does it want chemical tariffs cut on an across-the-board, or "formula" basis. Instead, the industry would like to see that whatever tariff cuts are agreed upon are made on the basis of specific requests from foreign countries.

Among other things, the U.S. chemical industry thinks that U.S. emphasis in the multilateral trade negotiations should be placed on improving market access for U.S. exporters, developing codes to cover foreign investment (both in the U.S. and by U.S. companies), intellectual property rights, and safeguards, as well as on improving the existing procedures for settling GATT disputes. At press time, trade officials expected that "framework agreements" on these and other trade issues would come out of the Montreal meeting. ☐

Deficit widens for U.S. chemical rade with Europe

Millions	1988[a]	1987	% change
.S. CHEMICAL EXPORTS			
anada	$ 3,939	$ 3,277	20%
atin America	4,992	4,407	13
estern Europe	9,425	7,987	18
astern Europe	335	344	−3
apan	4,007	3,422	17
ustralasia	1,034	834	24
ommunist Asia	1,495	808	85
iddle East	543	423	28
est of Asia	5,831	4,121	41
frica	565	500	17
ther	314	258	22
TOTAL	$32,500	$26,381	23%
.S. CHEMICAL IMPORTS			
anada	$ 3,845	$ 3,052	26%
atin America	1,270	942	35
estern Europe	10,275	8,220	25
astern Europe	203	165	23
apan	2,279	2,150	6
ustralasia	376	235	60
ommunist Asia	245	200	22
iddle East	308	238	29
est of Asia	856	698	23
frica	115	74	55
ther	328	239	37
TOTAL	$20,100	$16,213	24%

C&EN estimates. Source: Bureau of Census

Western Europe

Cautious optimism reigns as chemical demand stays high

Some industry analysts fear tight supplies now will spur a capacity buildup, leading to a future market glut

Patricia L. Layman, C&EN London

Buoyant. Glowing health. Renewed vitality. Unbelievable. These are just a few of the words used to describe the chemical industry in Western Europe during the past year.

By any measure, the industry has had a splendid year. A good 1987, in fact, turned out to have been only a dress rehearsal for the year that has followed. With nearly all petrochemical products in tight supply, a situation exacerbated in some cases by fires or other operating problems, selling prices have risen and producers' margins have strengthened to levels that are bringing joy to the hearts of corporate accountants.

Most people in the industry would agree with one company planner who believes that the industry's good fortunes this year are well deserved. "We went through a lot of pain in the early 1980s, with cost-cutting, rationalization, and layoffs. We're reaping the rewards now," he says.

Adds Mario Artali, executive vice president of Milan-based EniChem, with some understatement, "It has been a year in which managing companies has been very easy."

In light of so much positive comment, however, corporate and government crystal balls are hazy at best regarding 1989. Forecasters who saw their cautious optimism last year overwhelmed by surprisingly high growth, now are even more cautious about predicting the coming year. They are using phrases about present business conditions like "not sustainable" and "they can't last forever."

Economic policy, currency movements, political stability, consumer demand all are being factored into next year's forecasts. So, too, are the ramifications of the single internal market planned for the European Community in 1992 and now beginning to take definite shape, as well as the nagging presence of the Middle Eastern petrochemical plants as a potential threat to European marketers.

However, confidence is continuing, despite what probably will be a slight drop in the rate of economic growth during 1989. Growth in output for the chemical industry in Western Europe will average about 5.5% this year. Next year, the rate is expected to drop somewhat, to about 3%, says Alain van de Vaet, chief economist for the European Council of Chemical Manufacturers' Federations.

Says Neville Pinnington, senior division head for bulk petrochemicals at Shell International Chemicals in London: "At the end of last year, people asked, 'Will it continue through the first quarter or the first half?' It was cautious optimism then, because of our firm belief that the peaks and troughs of the economy are inevitable. However, their amplitude seems to be changing."

Why the change? Several companies agree that credit must go to the active economic policies of the Group of Seven—the seven major industrial nations: the U.S., the U.K., West Germany, France, Italy, Canada, and Japan. Montedison executives, for example, think that the successful coordination of policies among this group has resulted not only in relative stabilization of foreign currency exchange rates but also in continued economic growth.

Other companies point out that after the collapse on Wall Street in October 1987, the speed with which financial ministers got together boosted confidence and helped stabilize markets. Governments are looking at things on a global scale, the belief goes, and that is good for industry.

But some companies tend to be a bit more cautious now in their outlook, nevertheless. Although the prospect for next year certainly is better now than it had been earlier in the year, ICI economists say, they see a slowing in business growth in 1989 to as little as half of what it was in 1988, first in the U.S. but spreading later into Europe. However, they don't see any such slowdown influencing profitability in the chemical industry, at least before the seasonally weak third quarter of 1989.

This year, adds ICI, the seasonal summer slowdown was far less pronounced than usual, so that third-quarter profits were way above the levels of the year before. Indeed, according to Hans Albers, chairman of West Germany's BASF, "There was an almost total absence of any seasonal decline (in sales) during the summer months."

"For 1989, I don't think in terms of downturn," says EniChem's Artali. "I don't think 1989—especially in the plastics sector—will be as good as 1988. It will be a more reasonable year." What Artali sees as crucial, however, is a reactivation of companies' rationalization programs. "The danger of 1988 is that too many people have been convinced that most of the rationalization has been done. That is not correct. We have to rationalize not just by cutting capacity but by reorganizing the chemical industry itself. Making money has been easy, and we've needed a year like that. But 1988 can't be thought of as a standard year—that would be foolish."

Other companies agree with the need to rationalize further. For example, an economist at BP Chemicals points out a need "for rationalization or joint ventures in Western Europe, especially in polyethylene. There are 15 to 18 players, and that's still too many."

Montedison officials also think that a slowdown in 1989 could be avoided by increased concentration in the chemical industry. The industry could increase its profitability, they add, by closing plants in particular that are poorly located. Montedison and EniChem both believe that their joint venture, EniMont, which early next year will combine most of the chemical units of the two companies, is a good example of such rationalization.

More rationalization indeed should be done, add Neste officials, who think the 1990s will see a smaller number of larger producers in the marketplace. Officers at Atochem, the chemical arm of Elf Aquitaine in France, likewise agree that there are too many producers of commodity chemicals in Europe, compared with the U.S. or Japan, but they make the painful point that "it is difficult to bring about restructuring when everyone is earning a lot of money."

On the other hand, Antonio Sernia, vice president of EniChem, told the European Petrochemicals Association in Monte Carlo last September that there still is room for carefully considered building in the chemical industry. "We now have low raw material costs, high capacity utilization, and plants that have been mostly amortized," he said. "If we are realistic, we have to admit that low costs cannot be relied on indefinitely. Moreover, all production plants have their life cycle." Today's profit margins, he added, support a selective "scrap-and-build" policy. This is especially true where new plants can incorporate technological improvements to increase energy savings (one factor, he contends, responsible for pushing down the cost of crude oil) or where spending to reduce environmental problems will "ensure that we are not faced with a rapid escalation of regulatory pressures."

BASF's Albers notes that "for some products, growth now is limited by capacity bottlenecks. We are offsetting this by expansions. Strong stimuli are still apparent in our chemical operations."

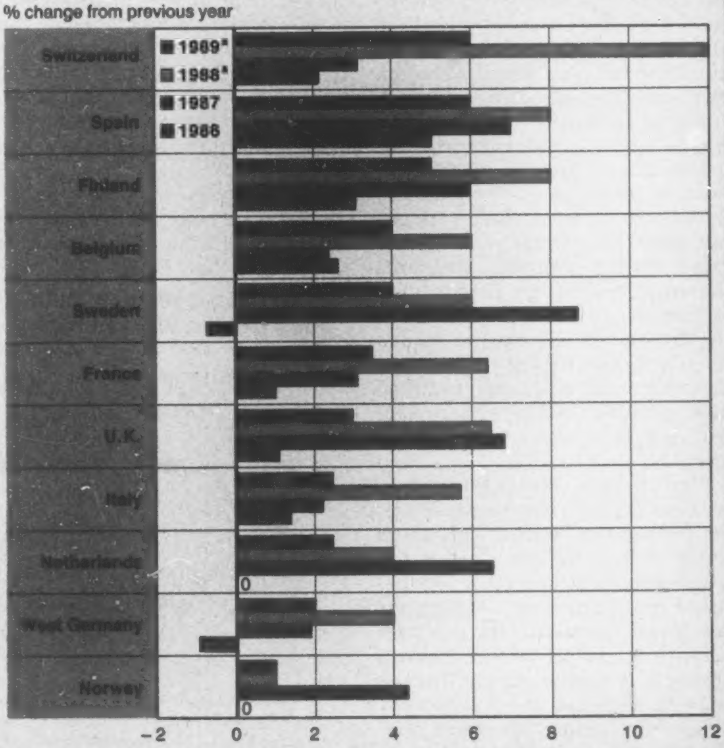
Part of the stimuli comes from what Shell's Pinnington terms a technological revolution in applications for plastics, fibers, and other materials. "People are doing a lot of downstream work on polymers: substituting, creating new applications," he points out. Growth during 1989 will slow down, he agrees, but nonetheless new applications are increasing and finding new end-use markets.

Among the more buoyant sectors in Western Europe is the motor vehicle industry, a major market for the chemical industry. Western European car production is on target for a best-ever total of 12.5 million units, up from last year's record 12.2 million, with production being stretched to meet demand. European autos still dominate the European market, moreover. Japanese cars, for example, account for only about 12% of registrations throughout Western Europe. That means most of the European auto industry's demand for chemicals is fed by Western European producers.

There are some clouds on the industry's horizon, however. The European Community's single internal market of 1992 eventually will have some impact on the chemical industry. There already is some dispute among EC members, for example, as to what percentage of EC-

Expansion of chemical output expected to slow next year

% change from previous year



ᵃ Estimated. Sources: National chemical federations for each country, C&EN estimates sourced parts qualifies a vehicle as "European"; the British, for example, claim it should be 60%, but the French are holding out for 80%. The relatively high proportion, in either case, has helped hold down imports. But it runs counter to the increasingly global nature of the entire motor vehicle industry, with its increasing emphasis on global sourcing—and concomitant global supplying of chemical products.

The 1992 integration clearly will involve some automotive standardization. The single market, for one thing, would remove such barriers as exhaust emissions standards that are fixed at a variety of levels. EC's own studies show cost savings in design and engineering, as well as tooling, marketing, and distribution.

Now in the messy process of being thrashed out are more uniform antipollution standards. Back in 1985, the Commission of the European Community agreed on several such standards: restrictions on carbon monoxide and hydrocarbons that probably would be tough enough to require catalytic converters for all new cars over 2 L in engine size. Cars with smaller engines also faced tightened, although progressively less stringent, standards, some of which also could be met by lean-burn engines. The initial deadlines agreed to by the commission broke down this year, so there is no current coherent target. But most auto industry observers think that antipollution standards inevitably will be tightened.

That, in turn, will mean increasing demand for the plastics needed to make lighter-weight vehicles, catalysts for pollution control, and even new gasoline additives to replace lead alkyls as octane boosters in gasoline.

Significant weakness this year in markets for both fibers and fertilizers in Western Europe figure high in forecasts for the coming year.

Consultants at Tecnon, a London-based consulting firm, for example, see the fibers market as weak for acrylics, mixed for polyamides, but strong for polyester. Acrylic demand remains depressed as fashions move away from knitted garments, says Tecnon, although demand for nylon is picking up somewhat, at least in such markets as hosiery, household textiles, and carpets.

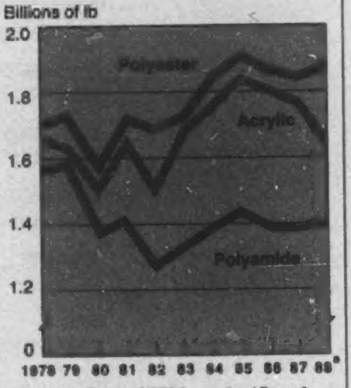
The fertilizer industry, meanwhile, continues to suffer from what many observers see as structural problems—still too much capacity for a market that will be slowly but inexorably shrinking in years to come. The situation has demanded major rationalization, such as that undertaken by Norsk Hydro with its Cofaz operations in France, which it purchased in 1987. In 1988, the company earmarked more than $150 million to modernize Cofaz facilities, as well as to restructure and streamline Hydro's own fertilizer production.

Output from the new facilities will replace that from older units in Cofaz, as well as imports to France from plants in the Netherlands, explains Finn Hvistendahl, managing director of Cofaz. Among his goals is to trim Cofaz's fixed costs and to reduce its labor force nearly 20%.

His colleague in Oslo, Trygve Refvem, head of Hydro's agricultural division, adds that in the European market for fertilizer, "prices are still so low that it is not possible for producers to operate at a profit. For Hydro, however, it is a clear target to operate so rationally that a reasonably good profit can be achieved, even with the present very low prices."

For European chemical producers, there are both positive and negative aspects to rapidly fluctuating currencies, particularly in the slide of the U.S. dollar during the past year or two.

Fiber output remains below 1985 level in West Europe



a Estimated. Source: CIRFS (International Rayon & Synthetic Fibers Committee)

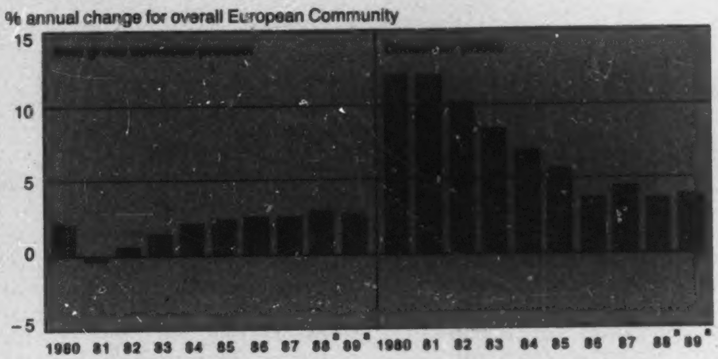
Although the chemical industry may not be so dramatically hit as some other industries, such as the auto industry, certainly profits from chemical operations owned by Western European companies in North America are being hurt when earnings in dollars are brought home and translated into stronger European currencies. However, a weaker dollar provides a significant benefit by restraining feedstock costs. Not only is oil currently much cheaper on an absolute price basis of about $15 or less per barrel than it was in the early 1980s, but that $15 is weaker, too.

Moreover, high capacity utilization—what Western European producers are calling "occupacity"—is resulting in higher chemical prices. And that, in turn, limits the effects caused by a weak dollar. Exceptions to this situation tend to be in markets where pricing is commonly in dollars, in textile fibers, for example, where weak pricing is compounded by overcapacity in Western Europe.

Wolfgang Hilger, chairman of the board of West Germany's Hoechst, notes that in fibers, "it had not up to now been possible to absorb the rise in raw-material prices by increases in selling prices."

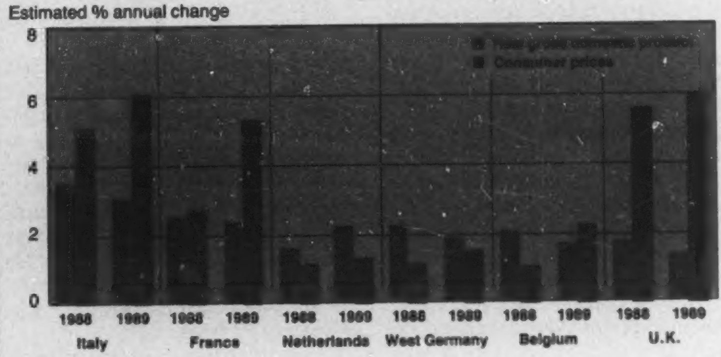
Chemicals are a significant export category for countries in Western Europe—indeed, they rank among the top five exports in most countries there. Much of the output, however, is still bound primarily for domestic destinations or to other European countries. Sales within these countries—particularly to and from countries with similarly stable currencies—suffer less from adverse currency translations than exports to weak-currency markets.

In the long run, however, currency fluctuations have relatively little impact on strategic planning for most chemical producers. Says a BP official, "We are looking at what we consider stable, long-term relationships between currencies. That's what you base investment on. The benefits of a new plant, for example, might be 10 to 15 years out. You have to think long-term."



Growth continues, with inflation restrained . . .

% annual change for overall European Community



. . . but output expansion will slow in most major countries

Estimated % annual change

a Estimated. Source: Commission of the European Community

Other companies—Akzo of the Netherlands and Degussa of West Germany, for example—agree that currency plays little part in their strategy. Says an Akzo spokesman: "Acquisitions and major investments are made for strategic reasons; currency fluctuations do not play an important role in the decision making." And Degussa officials add that the dollar position "has not at all influenced Degussa's decisions regarding acquisitions or expansions in the U.S. Our company rather is planning in long terms, with a view on the world's largest market."

Investment in new chemical plants next year in Western Europe undoubtedly will continue the trend of recent years of putting more money into specialty chemicals than in commodity operations. In 1988, too, new investment frequently was in the U.S.

Industrywide, capital spending is expected to slow a bit in 1989 from the pace of this year. Van de Vaet, for instance, forecasts that it will increase 6%, down from the exceptional rise this year of 9%. But with cash flow coming on strong for chemical companies, more of them are plowing more money into plant replacement, as well as into research and development.

Jim Gordon, chemical coordinator for the Shell group, notes that throughout the European chemical industry depreciation charges generally have been greater than capital investment. That has prompted a concern that the industry has not been reinvesting enough in its future, he says. In the past two or three years, however, that situation has been changing.

Much new investment must address environmental and pollution-control measures. Akzo, for one, says that pollution-control investment, as a share of its total capital spending budget, is expected to rise considerably; this year investment associated with the environment will account for about 15% of the company's total.

Few people in the industry quarrel with higher investment in R&D or environmental protection. But what clearly has the industry worried about the coming year is the prospect of a new wave of capacity buildup for all the petrochemicals and their derivatives that now are in tight supply.

Expansion as a result of debottlenecking and capacity-creep additions already is leading to significant growth in capacity. If growth rates for demand continue next year in the 3 to 4% range, these incremental expansions will only meet market needs. But if markets should grow 8 to 10%, that little expansion will be inadequate. Then, many in the industry fear, companies will rush headlong into building entire new plants, fearing that they cannot afford to be left behind, not if they want to continue to be a major player in the market.

Incremental expansions may push capacity utilization rates down to more desirable levels of 90 to 95% from the more than 100% level that has recently been the case for some plastics. How this is regarded depends on one's level of optimism. People worried about a potential economic downturn see capacity utilization falling to 85% or even below, so that current healthy profit margins will rapidly become more sickly. Two many people jumping on the expansion bandwagon would not help matters.

But no matter what investment decisions are taken during the coming year, they probably cannot be put into effect quickly enough to have a significant impact on the performance of the industry in the immediate future. □

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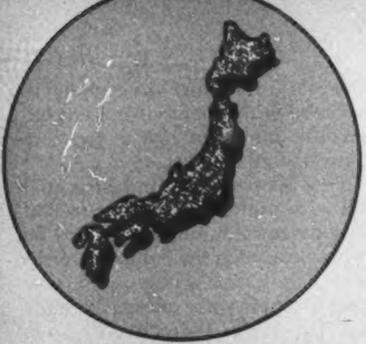

With demand strong, profits surge for chemical firms

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Despite its trade deficit, the chemical industry is flourishing and petrochemical supplies are tight

Earl V. Anderson
C&EN Northeast News Bureau

Japan's chemical industry, like several other of its industries, is proving that a lopsided trade surplus isn't needed to survive. The industry not only is surviving but flourishing without it. The chemical industry hasn't enjoyed a trade surplus since 1981. It won't have a trade surplus in 1988, either.

This year, in fact, Japan's chemical trade deficit probably will reach a new high—with chemical imports $800 million higher than chemical exports. Nevertheless Japan's chemical companies are turning in a strong performance this year.

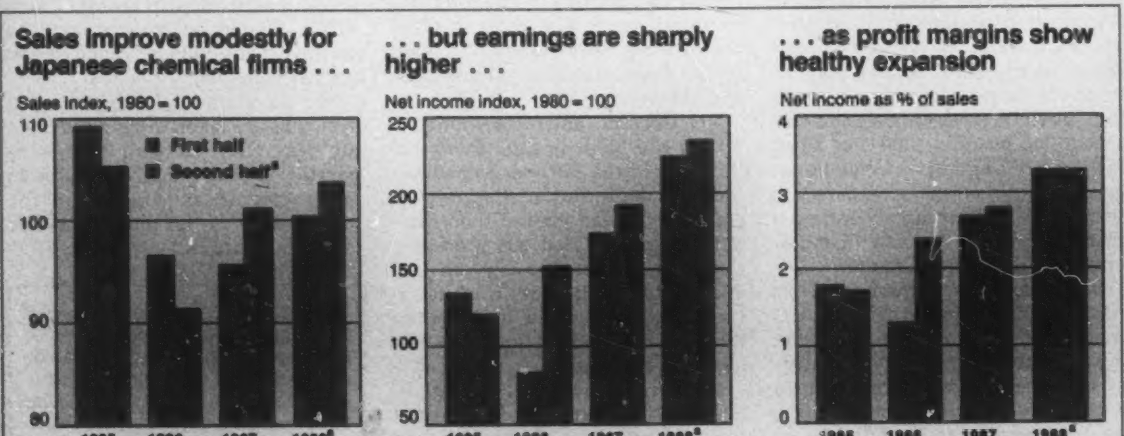
The reason lies close to home—in Japan's own geographically small but highly populated domestic market. Two years ago Japanese economic gurus warned that as the yen strengthened against the U.S. dollar, making it more difficult for all Japanese industry to compete in the international marketplace, the country's economic expansion would be derailed.

It would, that is, unless Japanese industries, including the chemical industry, reoriented themselves to thrive in a domestic-driven, rather than an export-driven, economy. Reorient they did. Spurred by strong consumer demand and high capital investment, Japan's domestic economy has been growing briskly since late last year.

Despite a downturn in the second quarter, in fact, the economy has been soaring. In the first quarter, gross national product grew at an annual rate of 11%. And indications are that economic growth picked up steam again in the third quarter, although expansion was not so strong as earlier in the year. This growth probably carried over into the fourth quarter as well.

Strong domestic demand, coupled with stringent cost-cutting programs, has been an elixir for Japanese company profits. According to a survey of 392 Japanese industrial companies conducted by the economic publisher Nihon Keizai Shimbun, corporate profits in the first half of fiscal 1988 (ended Sept. 30) were a heady 65% higher than in the first half of fiscal 1987, the highest gain in 15 years.

Chemical companies are participating in this profit surge. Although growth in their profits may not measure up to that for industry as a whole, a survey of a dozen major chemical producers indicates that the industry's profits were up a



Sales improve modestly for Japanese chemical firms . . .

. . . but earnings are sharply higher . . .

. . . as profit margins show healthy expansion

Note: Based on the results of 12 leading Japanese chemical companies: Asahi Chemical Industry, Dainippon Ink & Chemicals, Hitachi Chemical, Mitsubishi Kasei, Mitsubishi Petrochemicals, Mitsui Toatsu Chemicals, Sekisui Chemical, Showa Denko, Sumitomo Chemical, Takeda Chemical Industries, Teijin, and Toray Industries. The fiscal year for most, but not all, of these Japanese companies ends March 31 of the following year. a Estimated for second half. Source: Toyo Keizai Shinposha healthy 30% in the first half of fiscal 1988 and likely will increase 21% during the second half, which ends next March 31.

At least part of the difference between the chemical industry's 30% profit gain and the all-industry gain of 65% in the first half could lie in the fact that the Nihon Keizai Shimbun survey is based on profits before taxes and extraordinary items. The chemical industry results, based on estimates made by Toyo Keizai Shinposha, a Japanese financial publisher, reflect net profits after taxes.

However measured, chemical company profits will be more than satisfactory this year. Dainippon Ink & Chemicals, for instance, estimates that its pretax profits for this fiscal year will be up 18%. Unitika, the textile giant with substantial plastics operations, looks for a 14% gain. And Mitsubishi Kasei, Japan's largest integrated chemical company (which is changing its fiscal year), estimates that its pretax profits will increase 20% on an annual basis.

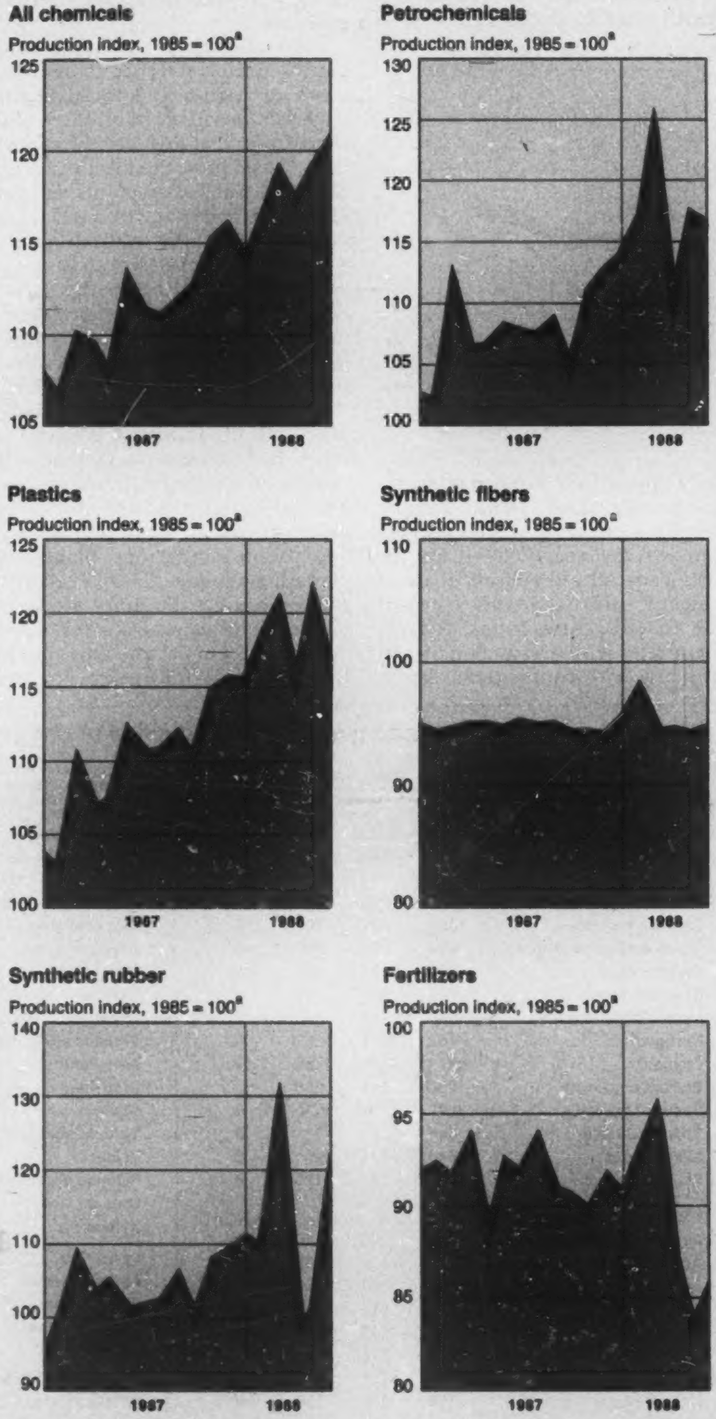
However, Showa Denko, another large, integrated chemical company, expects its pretax profits to almost double in fiscal 1988. The company is a microcosm of the Japanese chemical industry. In basic and intermediate petrochemicals, Showa Denko is benefiting from a combination of strong domestic demand and low naphtha prices, the primary petrochemical feedstock in Japan.

Meanwhile, its ceramics and engineering plastics operations typify the increasing tendency of Japanese chemical companies to move into products having a higher value-added. For Showa Denko, ceramics and engineering plastics are rapidly growing and very profitable businesses.

The Japan Fine Ceramics Association estimates that the market for fine ceramics will total between $30 million and $55 million by the end of the century, at current yen-dollar exchange rates. But ceramics are only one avenue that Japanese chemical companies are pursuing in their diversification drive into high-tech and high-value-added products.

Takeda Chemical Industries, Japan's top pharmaceutical company, is building two new laboratories to

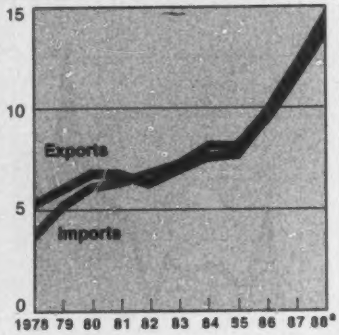
Chemical output rises strongly but fibers and fertilizers lag



a Seasonally adjusted. Source: Ministry of International Trade & Industry

Chemical exports, imports both soar in dollar terms

Foreign trade in chemicals, $ billions



a C&EN estimates
Source: Ministry of International Trade & Industry

study agricultural science and other nondrug areas. Denki Kagaku Kogyo's new long-range business plan—to the year 2000—calls for raising specialty chemicals' share of company sales from their present 28% to 60%. And Mitsui Toatsu Chemicals, which says that it can get along with conventional large-volume products "for the time being," is building a new life sciences lab.

Although Japanese chemical companies doubtlessly consider the move to high-tech and advanced materials very important, there also is no doubt that many of them now in the basic petrochemical industry can, as Mitsui Toatsu points out, get along with conventional large-volume products for the time being.

Japan's petrochemical industry is booming. According to the Japan Petrochemical Industry Association, no fewer than 12 major petrochemicals set new production records during the first nine months of 1988.

Ethylene production, the bellwether of the industry, is likely to top 5 million metric tons this year to set a new record. Output has not been so high since 1979. With ethylene capacity in Japan estimated at 5.2 million metric tons, plants are operating about as close to capacity as they can get. Supplies are tight for ethylene as well as for other major petrochemicals. Mitsubishi Petrochemical Industries, for the first time, actually is importing ethylene.

The Japanese Ministry of International Trade & Industry expects the petrochemical boom to continue, at least through the fourth quarter of calendar 1988. It estimates that demand for ethylene and its polyolefin derivatives will range from 2 to 5% higher than during the fourth quarter of 1987. MITI estimates that ethylene demand during this quarter will be 1.3 million metric tons, about the same as the nameplate capacity of the country's ethylene plants.

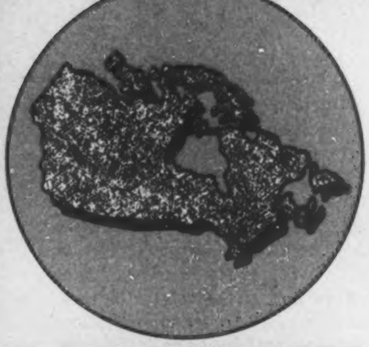
The Japan Petrochemical Industry Association believes that brisk petrochemical business can be expected even beyond the end of this year. "I have no serious concern about developments in the petrochemical business," says one association official.

This optimism could be justified. Economists in Japan see no slowdown in Japan's strong domestic consumption and investment, the two pillars on which the country's recent economic expansion has been based. ☐

Strong growth is widespread this year in production of chemicals

Thousands of metric tons unless otherwise indicated	1987	Six months 1988	Six months 1987	% change
INORGANIC CHEMICALS				
Ammonia	1784	889	871	2%
Ammonium chloride	332	153	185	−17
Ammonium sulfate	1804	906	897	1
Calcium carbide	354	202	200	1
Calcium superphosphate	499	254	269	−6
Carbon black	629	354	309	15
Chlorine, liquid	911	494	452	9
Hydrochloric acid	543	282	269	5
Nitrogen[a]	6452	3416	3162	8
Oxygen[a]	6878	3799	3189	19
Sodium carbonate	1098	542	558	−3
Sodium hydroxide	3227	1721	1575	9
Sodium silicate	664	341	313	9
Sulfuric acid	6541	3388	3259	2
Titanium dioxide	238	130	120	8
ORGANIC CHEMICALS				
Acetaldehyde	285	168	140	20
Acetic acid	367	192	165	16
Acetone	260	144	132	9
Acrylonitrile	573	288	271	6
Benzene[b]	2224	1159	1146	1
Butadiene	707	376	339	11
Butanol	259	127	120	6
Caprolactam	470	246	233	6
Cyclohexane	557	290	276	5%
Dioctyl phthalate	261	127	127	0
Ethylene	4585	2452	2262	8
Ethylene dichloride	2051	1093	1021	7
Ethylene glycol	313	183	167	10
Ethylene oxide	484	254	251	1
Methanol	161	113	85	33
Octanol	257	121	110	10
Phenol	308	180	162	11
Phthalic anhydride[b]	172	83	82	1
Propylene	3370	1798	1661	8
Propylene glycol	236	130	114	14
Styrene	1559	823	758	9
Terephthalic acid	1047	573	491	17
Toluene	881	511	428	19
Toluene diisocyanate	91	42	40	5
Urea	729	398	369	8
Xylene	1767	967	856	13
PLASTICS				
Phenolic resins	332	176	159	11
Polyethylene	2182	1124	1059	6
Polypropylene	1406	765	712	7
Polystyrene	1735	909	827	10
Polyvinyl chloride	1663	876	875	0
SYNTHETIC RUBBER	1192	655	586	12

a Millions of cubic meters. b Petroleum-based product only. Source: Ministry of International Trade & Industry



Rising exports buoy already surging chemical sales

Canada

With demand strong and supplies tight, Canadian producers are expanding their ethylene capacity

Earl V. Anderson
C&EN Northeast News Bureau

For the Canadian chemical industry, 1988 has been a very good year.

Although expansion in the Canadian economy is likely to slow down—1989 growth in gross domestic product is expected to be only about 2%, compared with 4% this year—the chemical industry probably will be able to squeeze at least one more good year out of what has so far been a six-year recovery from the 1981–82 recession.

For most Canadian chemical companies, and for most of their products, demand has been strong in both domestic and export markets throughout all of 1988. And although production is up virtually across the board, supplies are tight in many product areas, particularly in basic and intermediate petrochemicals. This situation has triggered higher prices for chemical products which, in turn, has meant much fatter—in fact, often record—profits for many Canadian chemical companies.

A good example is Celanese Canada. Through the first nine months of 1988, its sales were up 18% (on a Canadian dollar basis) to $237 million (in U.S. dollars; $1.00 = 1.24 Canadian dollars on Sept. 30). But net income was a hefty 87% higher than in the first nine months of 1987.

Much of the credit for the increased profitability company president Paul H. Williams attributes to the firm's chemicals and industrial products group. Celanese's methanol unit, for instance, has been operating at capacity, with prices increasing as recently as the third quarter. In Canada, methanol output in the first nine months was 1.5 million metric tons, 36% higher than last year's pace.

At Union Carbide Canada, sales ($339 million) were running 38% ahead of last year through the first nine months. But profits were up 79%, excluding an extraordinary gain from the sale of common shares in Polysar Energy & Chemical. A major factor in Carbide Canada's profit picture is the performance of Pétromont, the Montreal ethylene producer that Carbide owns jointly with Le Groupe SGF.

Pétromont, along with other Canadian ethylene producers, has been hard-pressed to meet demand. Production of ethylene in Canada is booming, buoyed by strong demand in such derivatives as polyethylene, polyvinyl chloride, and polystyrene.

Through the first nine months, total Canadian ethylene output was 1.73 million metric tons, 11% more than in the first three quarters of 1987. By year's end, it likely will reach at least 2.3 million metric tons, or perhaps even slightly more.

Both low-density polyethylene (LDPE) and high-density polyethylene (HDPE) are strong performers this year. Output probably will be, respectively, 1.1 million and 315,000 metric tons for the whole year, a 10% gain for LDPE and a 17% advance for HDPE.

Through the end of September, output of polystyrene, including acrylonitrile-butadiene-styrene resins, was up 11% to 163,000 metric tons. And, although production figures aren't reported for polyvinyl

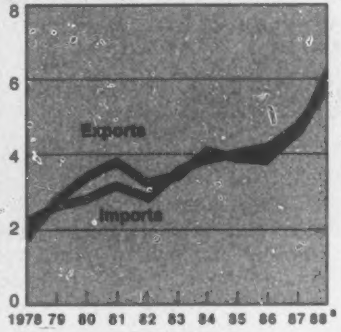
Production of fertilizer materials makes a strong comeback

	Production					% change
Thousands of metric tons	1988[a]	1987	1986	1985	1984	1987–88
Ammonia	4000	3512	3540	3620	3493	14%
Ammonium nitrate	1100	844	948	1054	969	30
Ammonium phosphate	945	941	1149	1301	1383	0
Benzene	690	720	635	588	557	−4
Chlorine	1650	1635	1536	1424	1424	1
Ethylene	2300	2140	1909	1744	1464	8
Hydrochloric acid, 100%	175	164	153	158	161	7
Phosphoric acid, 100%	450	464	547	627	691	−3
Polyethylene, high density	315	269	242	229	227	17
Polyethylene, low density	1125	1021	887	733	529	10
Propylene	630	628	628	648	665	0
Sodium chlorate	495	432	373	336	313	15
Sodium hydroxide	1720	1770	1696	1589	1575	−3
Sulfuric acid	3700	3437	3536	3890	4053	8
Urea	2700	2142	2330	2033	2110	26

a C&EN estimates. Source: Statistics Canada

Surge in chemical exports gives slight trade surplus

$ Billions (U.S.)



a C&EN estimates. Source: Statistics Canada

chloride, it's a safe bet that it, too, is running well ahead of last year.

With ethylene units operating at, or near, capacity, Canadian chemical companies are planning some major expansions for that basic petrochemical. Alberta Gas Ethylene (AGE) is building its third ethylene unit at Joffre, Alberta. A mammoth 680,000-metric-ton unit due on stream in 1992, it will raise AGE's total ethylene capacity at Joffre to just over 2 million metric tons per year.

Meanwhile, Dow Chemical Canada also will build a new ethylene plant in Alberta. The world-scale 450,000-metric-ton unit will be built at Fort Saskatchewan and may be on stream as early as 1993. And Polysar has received directors' approval to expand its ethylene capacity at Corunna, Ontario (near Sarnia). The expansion, which is expected to be completed by the first quarter of 1990, will increase capacity at Corunna 20% to 544,000 metric tons per year.

Even fertilizer, which has suffered through weak markets in recent years, is participating in this year's chemical bonanza. Ammonia output in Canada probably will be up 14% this year to 4 million metric tons. Urea production will rise a hefty 26% to 2.7 million metric tons. This turnaround is helping fertilizer companies' bottom line.

For fertilizer, as for many other chemicals produced in Canada, increased sales and profits are coming in good part from exports. Overall, Canadian chemical exports this year are expected to hit $6.2 billion, 26% higher than last year. About 62% are going to the U.S.

Imports, meanwhile, will increase 17% to $5.9 billion, with 75% of them coming from the U.S. The stronger export showing will give Canada a slight chemical trade surplus this year, compared with a slight deficit last year.

For next year, Du Pont Canada president J. Edward Newall probably sums it up best when he says, "We expect some softness in demand to develop if the widely forecast slowdown in economic growth materializes."

Certainly most economists think economic growth will slow, both in Canada and in the U.S., which is by far Canada's most important chemical export market. Although this undoubtedly will put a crimp in demand for Canadian chemicals, it could be a blessing in disguise if it relieves the threat of inflation, assuming an outright recession can be avoided.

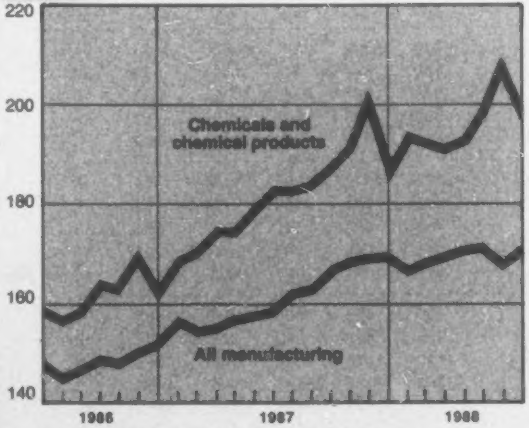
There are other economic factors that the Canadian chemical industry must also consider in 1989. One is the new free trade agreement with the U.S. If Canada approves the pact, as now seems assured, Canadian chemical companies will enjoy heftier profit margins, if not heftier sales, from exports to the U.S.

And then there are the fluctuations in the Canadian dollar. It has been strong against the U.S. dollar all year, hitting 84 cents (U.S.) late last month. It was as low as 72 cents in 1985.

Some Canadian exporters may have trouble competing in export markets and against imports into Canada at the current high levels for the Canadian dollar. However, many economists are predicting that the Canadian dollar will retreat to about the 78-cent level next year, which should make it easier for Canadian chemical firms to compete with their international rivals. ☐

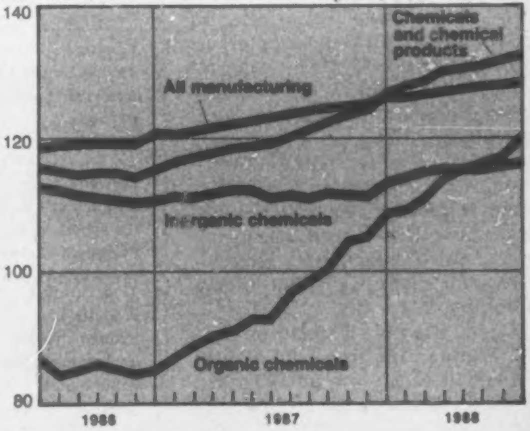
Chemical shipments are strong this year . . .

Shipments index,[a] 1980 = 100



. . . as chemical prices keep rising

Price index, 1981 = 100



a Seasonally adjusted. Source: Based on Statistics Canada data

Perestroika is revamping East bloc's chemical industry

U.S.S.R. / Eastern Europe

Chemical industry gets high priority in current industrial expansion plans of U.S.S.R., East Europe

Richard J. Seltzer, C&EN Washington

Economic, industrial, and political developments in the Soviet Union and Eastern Europe have come to be dominated by one word—perestroika, the far-reaching restructuring of economic and social mechanisms and institutions launched by Soviet leader Mikhail S. Gorbachev.

In the U.S.S.R., a package of reforms took effect at the beginning of 1988 for a significant fraction of chemical and other industrial enterprises, and additional enterprises will be transferred to "complete economic accountability and self-financing" on Jan. 1. The aim is to replace centralized, directive management of the enterprises with more decentralized and entrepreneurial decision making, to expand the role of such market incentives as prices, wages, and profits, and to cut back bureaucracies.

Restructuring processes are also under way in Hungary, Poland, Bulgaria, and Czechoslovakia. Only East Germany and Romania—under old-guard leaders Erich Honecker and Nicolae Ceauşescu, respectively—are resisting alteration of their centrally planned economic systems.

The reforms are going slowly and meeting with considerable opposition. Implementation so far has failed to bring many benefits, and has generated much confusion and controversy—perhaps even impeding economic and industrial growth in the short run—notes a recent report from the WEFA Group (formerly Wharton Econometric Forecasting Associates).

However, Soviet and most Eastern European leaders see no other way forward. "There will be no future for Poland if the industrial structure that has developed over the course of decades is not thoroughly changed," says the nation's new Prime Minister, Mieczyslaw Rakowski. Czechoslovakia must abandon its "well-used and dead-end paths," proclaims a government statement. The time has come for "profound socioeconomic changes," stresses an official Bulgarian newspaper. Several countries, such as Hungary, plan for periods of austerity, cuts in the standard of living, and temporary layoffs of workers as an "unwelcome but necessary concomitant of the restructuring of the economy."

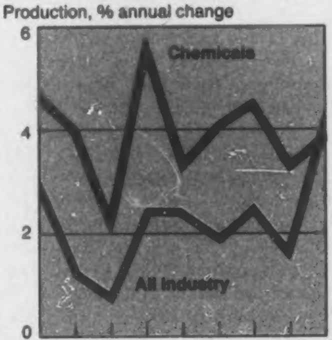
Nations of the region give high priority to their chemical industries in current five-year plans, now completing their third year. The Soviet Union, for instance, has adopted a comprehensive program for "chemicalization" of its national economy by the year 2000.

Top Soviet goals are to step up production of plastics, fibers, fertilizers, preservatives, pesticides, petrochemicals, dyes, and various chemical additives and reagents, according to Veniamin G. Afonin, chief of the Chemical Industry Department in the Communist Party Central Committee. The aim is to develop substitutes for expensive natural materials, simplify technology, and improve the quality and yields of agricultural products. And the Soviets are highly dependent on imported technology to make advanced chemical products, such as synthetic fibers and plastics, notes a recent U.S. Congressional report.

The five-year plans of nations in the region generally call for more rapid growth in the period 1986 through 1990 than was achieved or targeted in the previous five years. Thus, industrial output of the six Eastern European countries is supposed to rise 4.4% a year, compared with 2.8% annual growth from 1981 though 1985. Soviet industry is slated to raise output 4.6% a year, compared with 3.7% a year in the 1981–85 plan.

However, results this year and the past two years indicate that the 1990 targets will not be met. Last year, industrial growth slowed in the U.S.S.R. to 3.8% and in the oth-

Industrial output up this year in Soviet Union



Note: All figures except for 1988 are based on Central Intelligence Agency estimates, which are lower than official Soviet statistics because of postulated upward bias in Soviet figures. a Preliminary. b For first nine months; official Soviet figure for 1988 is for "chemical and timber complex," rather than just chemical industry. Sources: Central Intelligence Agency, U.S.S.R. State Committee for Statistics er six nations to 3.4%. Industrial output is growing faster this year, but not enough to make up the difference. Czechoslovakia, for example, has scaled back its industrial growth goal for 1989 to just 2.2%, well below the 3.5% a year envisaged in the five-year plan.

Soviet industrial output through September rose 4.3% compared with the same period last year (the 1988 goal is 4.5%). Hungary's output was up just 0.3% through August (the target is 1%).

However, Bulgaria's industrial output for the first nine months was up 5.4% (the 1988 goal is 5.0%). Czechoslovakia's output was up 2.6% through September (the goal is 2.3%). And East Germany's was up 7.9% in the first half of 1988. Poland's industry faltered in 1987, growing just 3.3%, but it rebounded with 6.3% growth through June this year.

Befitting its high-priority status, the Soviet chemical industry is growing faster this year than is industry overall. The Soviet "chemical and timber complex," for instance, raised output 3.9% in the first seven months of this year. The chemical component of this complex, the Ministry of the Chemical Industry, grew much faster than most other components, increasing production 6.7%. Another component, the Ministry of the Medical & Microbiological Industry, was up 6.9%. Growth was slower at the Ministry of the Timber Industry (4.4%), Ministry of the Production of Mineral Fertilizers (2.7%), and Ministry of Petroleum Refining & Petrochemical Industry (2.1%).

Soviet production of mineral fertilizers was up 3% through August compared with last year. Sulfuric acid and sodium hydroxide were each up 2%, synthetic fibers up 3%, and pharmaceuticals up 5%.

However, Soviet output of pesticides, measured through August, dropped 3% from the same period last year. And the U.S.S.R. State Committee for Statistics notes that the Ministry of the Chemical Industry is not fulfilling state orders for production of highly efficient types of plastics (polystyrene, polyvinyl chloride, polyethylene, and polypropylene), for thermoplastic pipes, and for detergents. Furthermore, a serious backlog has developed in some plants making basic raw materials. For example, almost half of 27 synthetic ammonia-producing units have not met targets through September, and sulfuric acid production was 478,000 metric tons below target.

Soviet chemical output up, but much of East Europe's lags

Thousands of metric tons, 1987	U.S.S.R.	Bulgaria	Czechoslovakia	East Germany	Hungary	Poland
Mineral fertilizers[a]	36,300	932	na	5100	na	na
Change from 1986	4.5%	−1.9%	na	1.1%	na	na
Nitrogen (N)	15,906	801	596	1300	600	1543
Change from 1986	4.5%	−2.1%	−2.9%	3.8%	2.7%	6.8%
Phosphate (P_2O_5)	9,697[b]	131	277[b]	300[b]	177	942
Change from 1986	4.5%	−0.8%	−9.8%	−3.0%	8.6%	−0.6%
Potassium (K_2O)	10,688[c]	—	na	3500	na	na
Change from 1986	4.5%	—	na	0.4%	na	na
Sulfuric acid, 100%	28,531	689	1264	866	573	3147
Change from 1986	2.5%	−14.6%	−2.2%	−2.0%	5.5%	6.1%
Ammonia[d]	20,470	1070	na	na	na	na
Change from 1986	4.5%	−2.0%	na	na	na	na
Plastics	5,500[e]	319	1152	na	539	639
Change from 1986	2.9%	−24.0%	1.1%	na	26.5%	1.1%
Sodium hydroxide, 100%	3,286	104	338	na	197[f]	425
Change from 1986	1.8%	−24.6%	0.9%	na	−2.5%	−0.5%
Synthetic rubber	2,360	25	75	85	na	117
Change from 1986	1.7%	0%	−1.3%	−28.0%	na	0.9%

Note: Romania is not included because of the unavailability of data on its chemical production in 1987. a Nutrient content basis. b Includes ground phosphate rock for direct application and phosphate animal feeds. c Imported potash added to domestically produced nitrogen and phosphate to form multinutrient fertilizer. d Nitrogen content basis. e Includes resins for man-made fibers. f Includes regenerated NaOH. na = not available. Sources: Central Intelligence Agency, state central statistical bureaus

Meanwhile, East Germany raised chemical production a remarkable 12% through June this year, compared with only 3.7% growth for all 1987. This was the highest of any industrial branch in the country except for electrical engineering and electronics. Output of high-density polyethylene was claimed to be up 82%, polyvinyl chloride 26%, and nitrogenous fertilizer 10%.

Czechoslovakia's chemical industry increased output 3.4% through September, surpassing its target. Two components of this industry also exceeded their goals—petrochemicals and crude oil refining (up 3.5%) and rubber and plastics (up 2.5%).

In addition, Bulgaria's biotechnological and chemical industry raised output 6.6% through June, recovering from just 1.3% growth in all 1987 and surpassing the 6.4% goal set for 1988. This growth was led by strong performances by plastics and high-value-added petrochemicals. Fine and specialty chemical production is slated to grow about 15% this year, as well.

Hungary's chemical industry grew 2.1% overall in the first eight months of 1988—but omitting the energy sector, output of chemicals climbed 5.8%. And Poland's chemical industry expanded at a 7.2% clip in the first half of 1988.

The Romanians release almost no economic and industrial statistics, and what they do release is extremely suspect. The nation's plan targets for 1988 are "pure fantasy, more unrealistic than ever," says one source. It set goals of a 9 to 10% rise in national income and 7 to 8% in industrial output, predicated on high growth in labor productivity by an "already demoralized work force."

The Romanian five-year plan calls for raising chemical and petrochemical output 50% and exports 70% between 1986 and 1990. Priorities are fine synthesis and small-tonnage chemistry, ultrapure substances, semiconductors and monocrystals, highly pure reagents, organic pigments, lacquers, and dyes. Romania's chemical industry already contributes 20% of the country's industrial output and 25% of its exports. □

DECEMBER 19, 1988

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CAPITAL SPENDING

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Page 9

CHEMICAL & ENGINEERING
NEWS

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DECEMBER 19, 1988

News of the Week

- **Centaur Partners, a New York City-based investors group, renews its bid to acquire Pennwalt.** **Page 4**
- **U.S. and Soviet science academies to launch cooperative study of global ecology.** **Page 5**
- **FDA approves five-minute AIDS test developed by Massachusetts biotechnology firm Cambridge BioScience.** **Page 5**
- **New study of U.S. science education describes and analyzes the educational environment as a whole.** **Page 5**
- **ACS Board, meeting in Washington, D.C., re-elected Ernest L. Eliel as chairman, took action on a number of other matters.** **Page 6**

Cover: Distillation column is put into place during expansion of Rohm & Haas' acrylic monomer plant at Deer Park, Tex.

Letters **2**

Concentrates
Business **7**
Government **12**
Science/Technology **23**

The Departments
Books **40**
ACS Comment **45**
Newscripts **76**

Government

Chemical industry has largely succeeded in complying with Title III regulations on hazardous chemical emissions; Heritage Foundation provides President-elect Bush with set of conservative environmental recommendations; U.S. is adamant on alleged Soviet violations of weapons treaties; EPA caseload for environmental violations reached new high in fiscal 1988; Administration's superconductivity initiative lacks direction, says educational association. **Page 13**

Science

Microinterferometric methods unravel key to behavior of thin liquid films, help study long-range ordering in microheterogeneous systems; first aluminum-nitrogen analog of borazine is synthesized. **Page 27**

Science Policy

Soviet scientists visiting U.S. describe reforms in science in U.S.S.R. generated by perestroika and glasnost; major study on materials science and engineering gets sneak preview. **Page 31**

Technology

Work on development and uses of catalytic materials advances along a broad front at Lawrence Berkeley Laboratory-based center; program seeks to find ways for smaller firms to cut waste generation. **Page 34**

ACS News

Mass firings of chemists may be waning, indicates latest report of the Committee on Professional Relations, the smallest since 1981. **Page 42**

Meetings

Deadlines and topics for ACS meetings in spring 1989, fall 1989, and later dates are included. **Page 47**

Business

Worldwide capital spending by U.S. chemical companies will rise moderately next year, spurred by continuing strong exports and demand, C&EN survey of major producers shows. **Page 9**

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LETTERS

Benzene carcinogenicity

SIR: A. C. Nixon's letter concerning benzene regulations (C&EN, Nov. 21, page 2) appears to imply that chronic exposure to benzene is not particularly hazardous. I hope that the bulk of chemists out there know better than that, but I feel compelled to respond for the sake of those who don't.

Aside from its acute narcotic effects, benzene is toxic to the blood-forming tissues. Blood disease due to chronic benzene poisoning has been recognized since the turn of the century. Epidemiologic studies indicate a significantly increased rate of leukemia in industrial workers chronically exposed to benzene. For more details, I refer interested readers to a review by Peter F. Infante and Mary C. White in *Environmental Health Perspectives* (**52**, 75).

Interestingly, the article that provoked Nixon's letter (C&EN, Aug. 22, page 22) was concerned not with the question of whether benzene is a carcinogen, nor with the scientific controversy over assessing cancer risk at low exposure levels, but rather with the political issue of what level of risk—for example, what number of excess cancer deaths in the population—is acceptable to our society. It appears that Nixon is attempting to duck the political question by obfuscating the underlying fact of benzene carcinogenicity.

Margaret Levin Phillips
Baltimore, Md.

Extradition clarification

SIR: I would like to point out an inaccuracy that appears in the article, "Bhopal Litigation Reaches India Supreme Court" (C&EN, Nov. 28, page 7) with respect to the extradition of Warren Anderson to India.

You have attributed to me the belief that "serious attempts to extradite Anderson could be made by India through the Uniform Enforcement of Foreign Judgments Act." Although I believe that the government of India is serious about extraditing Anderson, such extradition procedures could not be made pursuant to the Uniform Enforcement of Foreign Judgments Act. That act is applicable to enforcement of civil money judgments rendered by the Indian courts, but it has no application whatsoever to a foreign criminal charge or indictment.

My law firm has not been retained by the Indian government with respect to the criminal charges arising out of the Bhopal disaster, and, consequently, we have had no involvement in the efforts to extradite Anderson. Instead, our involvement has been only with respect to the civil case against Union Carbide Corp.

Bruce A. Finzen
Robins, Kaplan, Miller & Ciresi
Attorneys at Law
Minneapolis, Minn.

General chemistry courses

SIR: The recent discussion, "Refocusing of the General Chemistry Curriculum" (C&EN, Oct. 17, page 25), left me with a feeling of déjà vu and disappointment.

If we wish to present a relevant introduction to chemistry that will

(1) inform students of general chemistry—including those who, a priori, are not interested in a professional future in our field—about the crucial contributions of chemical science and technology to the well being of the nation; and

(2) reinforce the motivation and, at the same time, broaden the vision of those students who, for whatever personal reasons, are already attracted to careers in chemistry, chemical engineering, and allied specializations such as material science, biological chemistry, and so on, then educators must search for a common denominator that affects the thinking of the predominant majority of all citizens, and show how our profession responds in countless ways to this ever-present concern.

In the era of consumerism in which we live, this common denominator is the economy as witnessed by daily reports of such economic indicators as the rate of unemployment, housing starts, consumer confidence, changes in the gross national product, investment confidence as reflected by changes on the stock market, and so on. These econometric reports influence the behavior of most of the citizenry not only in the marketplace but also in career choices and political decisions.

The general public, and its young who reach us in general chemistry, must acquire a clear understanding that chemistry, directly or indirectly, is deeply involved in the production of improved and convenient food products and shelters, modern communication devices, modern means of transportation, structural materials for all purposes, modern tools to fight health problems—to mention just a few categories of products that improve the quality of life generally taken for granted. The general public must be made to understand that the transformation of materials to higher-value-added products generates true wealth and provides sound

Chemical Capital Spending To Continue Increasing

Strong exports and domestic sales are still squeezing capacity use, spurring major U.S. chemical firms to boost plant and equipment spending

Marc S. Reisch,
C&EN Northeast News Bureau

Worldwide capital spending by U.S. chemical companies will increase moderately in 1989, according to preliminary forecasts by leading chemical producers. Only nine of the 12 major chemical producers that C&EN surveys every year at this time were able to forecast their 1989 expenditures. For those nine companies, 1989 capital spending will rise 14% from 1988 to a combined $4.95 billion. That forecast follows a monumental 31% increase in 1988 capital spending from the previous year.

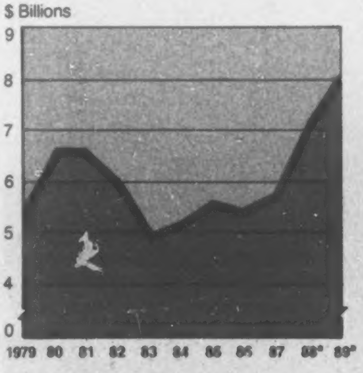
A stronger than expected economy in 1988 apparently has caught at least two chemical companies off guard, and so this year they do not feel confident in making their usual early capital spending forecasts. Hercules and Monsanto, who together spent $820 million in 1988 on capital projects, have not provided a 1989 forecast. Nor has Du Pont, but its board of directors frequently meets so late in the month that its forecast cannot be included in C&EN's December survey.

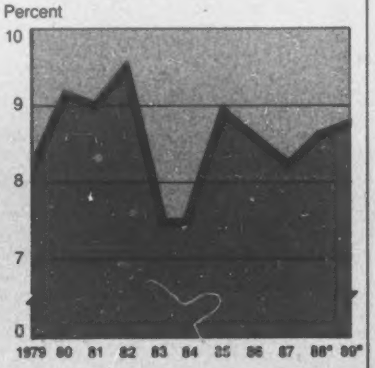
So the 1989 forecast is based on Air Products & Chemicals, American Cyanamid, Dow Chemical, Ethyl Corp., W. R. Grace & Co., Olin, PPG Industries, Rohm & Haas, and Union Carbide. Like previous years' surveys, this year's sampling of 1989 spending forecasts indicates a trend for the entire chemical industry's capital spending next year. Although the survey provides nine distinct decisions on the direction that management feels capital expenditures will take in 1989, it lacks Du Pont's numbers, which made up almost a third of 1987 capital expenditures for the group of 12, and also Hercules' and Monsanto's numbers, which represented 12% of the group's spending in 1987.

Of course conditions change during the year and company spending can greatly exceed the amount management originally planned. Air Products, for instance, originally planned to spend $400 million in 1988, but instead reports it spent closer to $542 million this year—36% higher. In six cases, actual 1988 expenditures exceeded capital expenditures planned for 1988. The same group of companies surveyed last year on planned 1988 capital expenditures, excluding Du Pont, collectively forecast expenditures 20% ahead of 1987, but actually report they spent 31% above their 1987 spending levels.

Last year at this time, 1988 was not expected to be so strong a year as it was. Chemical industry economists were predicting strong sales to overseas customers because of the decline of the dollar relative to most other world currencies. But housing and automobile markets were expected to remain soft, and agriculture only had slightly better prospects coming out of a period of steep decline.

This year has proved to be a strong year for exports. It has proved to be a very strong year for domestic sales in all categories as well. With demand so high for most products, supplies are tight and therefore capacity use has been high as well. The shortness in supplies of some chemical products such as ethylene has allowed for price increases that in some cases are very high. As a result, C&EN has adjusted its 1988 estimate of industry capital spending as a percentage of sales: Last year industry capital spending as a percentage of sales for 1988 was projected at 9.3% (C&EN, Dec. 21, 1987,


Chemical capital spending will rise moderately...


...and also will increase as a percentage of sales

Note: Combined data from 12 major chemical producers listed on page 10. a C&EN estimates.

Capital spending of surveyed companies will increase 14% next year

	1989		1988		Worldwide					Change from previous year	
$ Million	Total	U.S.	Total	U.S.	1988 planned[a]	1987	1986	1985	1984	1989	1988
Air Products[b]	$ 550	na	$ 542	na	$ 400	$ 323	$ 367	$ 392	$ 263	1.5%	67.8%
American Cyanamid	350	$ 280	350	$ 280	350	268	263	203	200	0	30.6
Dow Chemical	1650	950	1250	750	1200	995	890	806	761	32.0	25.6
Du Pont[c]	na	na	na	na	na	1824	1587	1515	1319	na	na
Ethyl	150	135	125	115	150	139	134	90	103	20.0	−10.1
W. R. Grace	475	210	430	270	400	243	199	348	380	10.5	77.0
Hercules	na	na	250	195	250	205	257	234	218	na	22.0
Monsanto	na	na	570	390	513	505	520	645	614	na	12.9
Olin	130	na	150	na	158	115	128	154	165	−13.3	30.4
PPG Industries	500	375	425	300	450	426	356	452	315	17.6	−0.2
Rohm & Haas	350	235	330	210	300	222	179	159	124	6.1	48.6
Union Carbide	800	560	740	518	580	502	524	649	670	8.1	47.4
TOTAL	$4955	$2745	$5162	$3028	$4751	$5767	$5404	$5647	$5152		
ANNUAL CHANGE[d]	14%	12%	31%	16%		7%	−4%	10%	5%		

a Earliest estimate. b Fiscal year ends Sept. 30. c Excludes Conoco. d Cumulative change for companies reporting. na = not available.

page 9), but more recent calculations put that figure close to 8.7%.

During the first nine months of 1988, sales for the 15 largest chemical companies rose about 20% from a year earlier (C&EN, Nov. 14, page 24). Because of that stellar performance and the increases in 1988 capital expenditures companies reported for this survey, C&EN has revised upward its capital spending estimate for the group of 12 to $7.26 billion from the $6.84 billion forecast in last year's survey.

For next year, high demand and high operating plant rates for base petrochemicals and polymers are expected, according to William C. Kuhlke, vice president of DeWitt & Co., Houston consultants. He adds that "1989 will see a more balanced supply/demand market characterized by continuing high prices, good profitability, and the possibility of spot shortages."

With demand remaining strong, and with relatively stable price conditions for petrochemical feedstocks, chemical companies have an incentive to expand petrochemical output. In fact, many companies have announced expansions in basic petrochemicals, a scenario no one could have expected following the rash of shutdowns and capacity rationalizations after the recession of 1982. The Houston Gulf Coast area seems to be benefiting from the high demand in petrochemicals. At a recent press conference in New York City sponsored by the Houston Economic Development Council, Ray Porter, manager of industrial development at Houston Lighting & Power Co., said that $3.1 billion in capital projects have been announced in the Houston area during the year ended in November—twice the value of projects announced in the same survey in 1987.

As an additional incentive to build domestic capacity, Richard A. Stuckey, Du Pont's chief economist, points out that chemical imports rose 8% last year and he estimates the rise this year has been about 22%. The resurgence of imports comes on a relatively low base and has served to keep user plants operating. But he finds the increase disturbing nevertheless. He predicts, though, that the U.S. chemical trade surplus will be at or near the all-time record of $12.1 billion in 1988, up from $10 billion last year.

The 14% increase in capital spending forecast for next year pales by comparison with 1988's 31% increase. However, 1988 seems to have been a watershed year when chemical companies realized they could not just make do with debottlenecking projects and small expansions, but they would have to commit to significant capacity expansions to satisfy the demand for products.

Even with the 31% boost in capital spending reported for the group of surveyed companies, a number of companies individually boosted their spending for the year at a

Chemical plant construction was up markedly this year much higher rate. Grace, for instance, increased its 1988 capital spending 77% to $430 million. That hike continues to reflect the increased emphasis Grace has placed on the specialty chemical business since it spun off its retailing and restaurant operations.

Also up significantly was Air Products' spending, rising 68% to $542 million. The figure includes the acquisition of capital assets when Air Products acquired Anchor Chemical in December 1987 (Air Products reports its results on a fiscal year basis and purchases made in the last quarter of 1987 are included in fiscal 1988 results). A company spokesman points out that its capital expenses figure includes significant spending to upgrade existing units and the addition of efficient capacity.

Other chemical producers reporting higher increases in capital spending than the group average are Rohm & Haas, with a 49% increase to $330 million, and Union Carbide, with a spending boost of 47% to $740 million.

Five chemical producers reported capital expenditures under the 1988 average for the group but still well ahead of inflation. American Cyanamid increased its expenditures at a pace close to that for the group at almost 31% to $350 million. Olin also was close, with a 30% increase to $150 million. Dow Chemical increased its 1988 spending 26% on an already substantial base to $1.25 billion. Hercules also increased its spending well ahead of inflation, up 22% to $250 million; and Monsanto increased its capital spending 13% to $570 million.

Only two chemical companies did not invest at a double-digit rate of increase in 1988. PPG Industries investments in capital equipment actually declined 0.2% and Ethyl had an even greater drop of 10% to $125 million.

Seven of the nine chemical companies who could forecast their 1989 capital expenditures plan increased spending. Following strong sales and earnings in 1988, Dow Chemical leads the pack with an increase in its spending forecast at 32% above 1988 expenditures, more than double the average 14% boost planned for the nine companies, to $1.65 billion.

Others planning sizable spending increases in 1989 include PPG Industries, which forecasts an 18% increase from 1988 to $500 million, and Ethyl, which plans a 20% increase to $150 million.

Smaller increases in capital spending are planned by Union Carbide, up 8.1% to $800 million; Rohm & Haas, up 6.1% to $350 million; and Air Products, up a modest 1.5% to $550 million. American Cyanamid says at this time that it plans no increase in its 1989 capital expenditures and will spend $350 million, the same amount it estimates for 1988. Olin expects the only actual drop in 1989 capital spending—down 13% to $130 million.

As in last year's survey, companies responding to C&EN's inquiries increased capital expenditures in the U.S. at a slower pace than worldwide. Of the nine companies providing data, 1988 capital expenditures in the U.S. rose 16% from 1987 spending, about half the rate of worldwide spending increases reported by 11 of the 12 companies in the survey. The forecast for 1989 shows that the level of U.S. spending increases remains below the 14% predicted for worldwide capital expenditures. ☐

West German chemical giants plan modest spending hikes

West Germany's three largest chemical companies—BASF, Bayer, and Hoechst—plan modest increases in their capital expenditure programs for 1989 to $5.66 billion worldwide and $1.08 billion for their U.S.-based operations. As a group, they plan to spend 6% more than their estimated 1988 expenditures worldwide, and 5% more than their U.S. expenditures this year (figures are based on a conversion rate of $1.00 = 1.7 deutsche marks for both 1988 and 1989).

Like their U.S. counterparts, the three companies spent considerably more in 1988 than they originally planned in last year's survey. Worldwide expenditures of the three were up 25% to $5.36 billion in 1988 compared with 1987. U.S. spending was up even more dramatically, 37% in 1988 to $1.03 billion.

Thus, for 1988 the West German chemical companies' spending patterns were exactly opposite that of their U.S. competitors. While U.S. chemical producers increased their spending worldwide at a faster pace than they did in the U.S., BASF, Bayer, and Hoechst boosted their spending in the U.S. at a much faster pace than they did worldwide. For 1989, the three companies, like their U.S. counterparts, predict they will allow their U.S. investments to lag their worldwide expenditures.

Like their U.S. counterparts, the West German chemical companies increased their 1988 chemical spending beyond their original plans. In last year's survey (C&EN, Dec. 21, 1987, page 11), they planned to increase 1988 worldwide spending only 7% and U.S. spending 23%.

In this year's survey, Bayer is the only company planning a double-digit capital spending boost, 10% in 1989 to $1.89 billion. Hoechst and BASF lag much further behind. Hoechst plans a 3.6% boost in 1989 to $1.71 billion and BASF a 3.3% hike to $2.07 billion.

As for U.S. capital spending next year, Hoechst plans to keep expenditures for its U.S. operating unit, Hoechst Celanese, at the $350 million level it reports for 1988. BASF plans to raise U.S. capital investment nearly 6% in 1989 to $450 million. Bayer forecasts the largest increase, 12% to $280 million.

	1989		1988		Change from previous year	
$ Millions[a]	Total	U.S.	Total	U.S.	1989	1988
BASF	$2065	$ 450	$2000	$ 425	3.3%	30.5%
Bayer	1888	280	1711	250	10.3	20.1
Hoechst	1711	350	1652	350	3.6	24.2
TOTAL	**$5664**	**$1080**	**$5363**	**$1025**		
ANNUAL CHANGE	**6%**	**5%**	**25%**	**37%**		

[a] $1.00 = 1.7 deutsche marks.

Mass Terminations of Chemists Finally May Be on the Decline

In one way the latest report by ACS's Committee on Professional Relations (CPR) on multiple terminations of chemical professionals represents good news. It is the smallest such report since 1981. It covers just five such mass firings and involves a total of only 42 chemists and chemical engineers. The previous report covered eight terminations involving more than 200 chemical professionals (C&EN, Aug. 15, page 31).

Only time will tell if the new report reflects an end to the major chemical industry restructurings of recent years. Such reorganizations in many cases have been necessary to keep operations competitive and viable. But they have cost many chemists, especially older ones, their jobs.

There are at least two other positive aspects to the latest report. In three of the four terminations for which there are sufficient data to make a judgment, terminees were apparently treated relatively well. Also none of the firings involved the restrictive termination agreements of the type that has been of concern to CPR lately.

Employer compliance with ACS employment guidelines

These employers provided information	Approximate number of employees separated	Advance notice	Severance pay	Assistance	Pension vesting	Employee service	Protection plans
Miles, subsidiary of Bayer USA (Elkhart, Ind.)	15	☐	▨	☐	☐	■	☐
PPG Industries, Chemical Division (Barberton, Ohio)	9	☐	☐	☐	☐	■	☐
Westinghouse Hanford (Richland, Wash.)	7	☐	▨	☐	☐	▨	☐

These employers provided no information; hence, all ratings based on terminee responses

Battelle Memorial Institute (Richland, Wash.)	3	*	*	*	*	*	*
SeaPharm (Fort Pierce, Fla.)	8	■	■	■	■	☐	■

*No information from any source.

☐ Employer met or exceeded guideline standard.

▨ Two or more individuals below guideline standard, but average experience better than "substantially below" criterion.

■ Employer was substantially below guideline standard, which is defined as follows:

- Advance notice—less than two weeks.
- Assistance—no assistance rendered.
- Severance pay—less than one week per year of service.
- Employee service—more than 40% of terminees had 10 or more years of service.
- Protection plans—no continuation of protection plans.

The latest report is the 28th in a series produced by CPR since 1974. They all compare the performance of employers having terminations with standards spelled out in ACS's Professional Employment Guidelines (PEG). These standards are concerned with advance notice, severance pay, assistance in finding new employment, pension vesting, length of terminee's service, and extension of protection plans.

Compliance with these standards is at 58% in the latest report. This is substantially higher than the 48% long-term average for the previous 27 reports.

The largest termination covered in the new report was at Bayer USA's Miles subsidiary. Resulting from what the company describes as a "redirection of priorities," it involved the involuntary separation of 15 chemists and chemical engineers. The other terminations involved nine chemical professionals at PPG Industries, eight at SeaPharm, seven at Westinghouse Hanford, and three at Battelle Memorial Institute. According to CPR, the cutbacks at both Westinghouse and Battelle resulted from termination of some nuclear waste studies, and the firings at SeaPharm may have been related to the filing of a petition for bankruptcy by the company.

CPR has no other verified mass terminations under investigation, although some unverified reports of such firings are being examined. A mass termination is defined by CPR as a situation in which the employment of three or more chemical professionals is terminated within a six-month period for reasons other than continuation of previously documented inadequate performance, completion of a contract, or cause. All terminess need not have worked at the same location.

ACS guidelines

Advance notice. Four-week minimum.

Severance pay. Minimum is two weeks per year of service. Additional notice may be given, by mutual agreement, in lieu of severance pay.

Assistance. Efforts should be made to place terminee in another position within the organization, or terminee should be given assistance to find employment elsewhere.

Pension plan vesting. Full vesting after 10 years' service.

Employee service. Those with minimum of 10 years' service should not be terminated except for continued evidence of previously documented inadequate performance or cause.

Employee protection plans. Should be extended for a minimum of one month, plus two weeks for each year of employee service, following termination, at same rate of contribution as before. Employee would have additional 31-day grace period.

CPR seeks information on terminations from employers, ACS local sections, terminees, and other individuals. In the latest report three of the five employers provided at least some data, as did the Akron and Richland local sections. The committee will provide copies of termination reports as well as a summary list of all terminations on request to American Chemical Society, Office of Professional Relations, 1155—16th St., N.W., Washington, D.C. 20036.

The PEG standard on employee service states that those with a minimum of 10 years of service should not be terminated, except for continued inadequate performance or cause. However, 77% of all terminations investigated by CPR to date have involved such experienced chemical professionals. And older chemists continue to be particularly vulnerable in termination situations, an issue of continuing concern to CPR. In the latest report only the terminations at SeaPharm did not involve experienced chemists.

Michael Heylin

Call for nominations for polymer award

The ACS Division of Polymer Chemistry is inviting nominations for the 5th Creative Polymer Chemistry Award. The award will be presented at the division's fall 1989 meeting, and is given to recognize and encourage accomplishment and/or innovation of unusual merit in the field of basic or applied polymer chemistry by younger scientists. It consists of a plaque and $2000 and is presented biennially in odd-numbered years, provided a qualified person is available. Travel expenses to the division's fall meeting will be paid. The recipient is expected to present a lecture at the meeting.

The award, sponsored by Dow Chemical Co., was established in 1980, and is administered by the division. A nominee must be a member or affiliate of the division, must have accomplished outstanding work in basic or applied polymer chemistry, and shall not have reached the 45th birthday on Jan. 1 of the year of the award.

Eight copies of the complete nominating document (including date of birth, membership status, a synopsis of the accomplishments of the nominee, and a maximum of five reprints or other supplementary material for each copy), letter-size and unbound, must be furnished for distribution to the members of the awards committee. A maximum of three supporting letters (eight copies each) that contain factual information about the candidate not provided in the nominating document may be included as part of the nomination. The nomination and its accompanying material must be postmarked no later than midnight, Jan. 31, and sent to H. James Harwood, Department of Polymer Science, University of Akron, Akron, Ohio 44325. □

C&EN staff photo

Bust of Carl Marvel dedicated at ACS headquarters

A life-size bronze bust of the late polymer chemist Carl Shipp Marvel was dedicated recently at ACS headquarters by Du Pont chairman and chief executive officer Richard E. Heckert. Du Pont commissioned sculptor Charles C. Parks to make the bust after Marvel's death earlier this year. The bust, which was unveiled at the 3rd Chemical Congress of North America in Toronto in June, commemorates Marvel's long association with ACS and will be placed near the entrance to Marvel Hall at ACS headquarters. The hall was named at the request of a number of Marvel's students who contributed generously to the building fund for the ACS headquarters building opened in 1960. Marvel, known to his students and associates at the University of Illinois as "Speed," directed research on synthetic rubber and is known as the father of high-temperature polymers. He worked as a consultant for Du Pont for nearly 60 years.

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JANUARY 16, 1989

CHEMICAL & ENGINEERING
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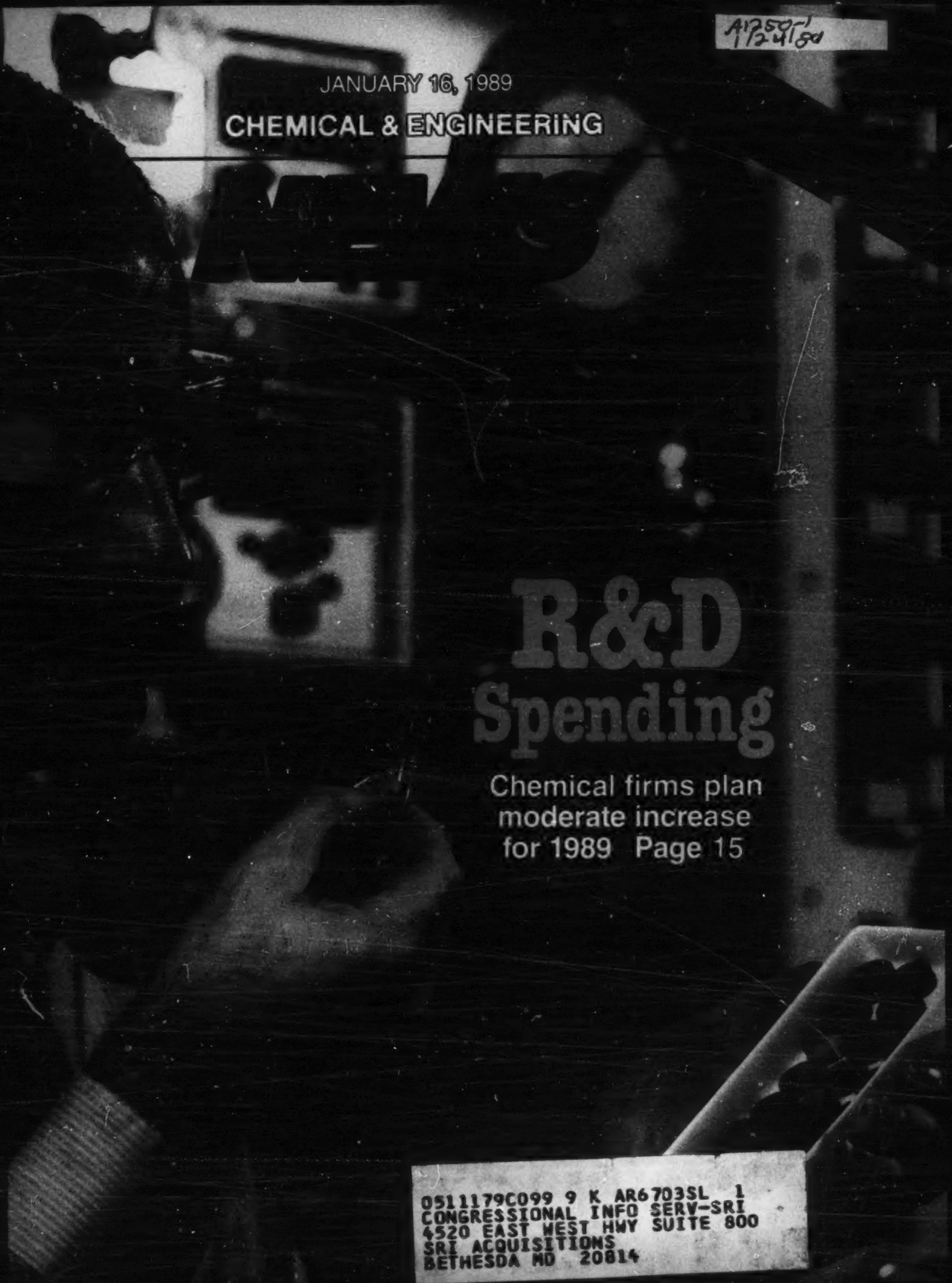

R&D Spending

Chemical firms plan
moderate increase
for 1989 Page 15

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News of the Week

- **In his final budget, submitted to Congress last week, President Reagan proposes 7% rise in federal R&D spending for fiscal 1990. Page 6**
- **Chemical arms concerns were focus of meeting in Paris attended by nearly 150 nations. Page 7**
- **European chemical production will slow in 1989, say British and European industry groups. Page 7**
- **Study by American Association for Clinical Chemistry shows that labs can achieve nearly 100% accuracy in testing for illegal drugs in urine. Page 8**

Cover: W. R. Grace scientist examines superconductor samples at Washington Research Center in Columbia, Md.

Letters 4
Editor's Page 5

Concentrates
Business 13
Government 21
Science/Technology 30

The Departments
Books 44
ACS Comment 50
People 53
New Products 58
Newscripts 84

Business

Changing markets and innovations are providing new growth opportunities for industrial gases, according to a recent study; a Union Carbide-led team helped erect shelters made of plastic film and steel piping in the earthquake-ravaged city of Spitak, Armenia. **Page 19**

Government

Study aimed at helping new Administration tackle environmental problems claims market-oriented approach is more effective, less costly; plethora of advice for Bush on a range of issues is rolling in from the scientific and technical community. **Page 22**

Science

Structure of protein encoded by mutant human oncogene is determined by chemists at the University of California, Berkeley. **Page 31**

Education

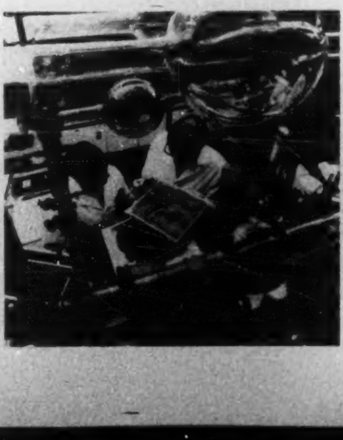
Management-of-technology M.S. program launched via satellite broadcasting. **Page 34**

Technology

Benchtop atomic-emission detector for gas chromatography introduced by Hewlett-Packard; NRC panel spotlights problem areas in shuttle booster redesign. **Page 37**

Meetings

Preliminary program for ACS national meeting in Dallas lists symposia, includes advance registration form. **Page 55**



Cover Story

Major U.S. chemical producers plan a moderate 9% increase in R&D spending in 1989, according to a survey by C&EN. Page 15

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LETTERS

Combating chemophobia

SIR: Several years ago, a few miles from some of the greatest centers of chemical education in the country, the Bay Bridge between San Francisco and Oakland was closed for seven hours following the spillage of one 50-lb bag of talc.

The general reaction of the chemical industry to this kind of irrational chemophobia has been a chemophobic panic of its own—the elimination of "chemical" from corporate names, and of "chemistry" from descriptions of its activities.

Meanwhile, day in and day out, the business of chemicals has become fair game for sensation-mongering by the press and by television news. This week, a bylined story in the *San Francisco Chronicle* described industrial alcohol as "a deadly chemical." The expression "cancer causing," used ignorantly and irresponsibly, is heard almost daily on the news.

Editors and TV station managers are, in my experience, sensitive to factual criticism. We have them outnumbered, these keepers of the chemophobia flame. Let's jump on their stories, in writing, until they get their facts straight.

Tom Cleary
Mendocino, Calif.

Priestley Medal address

SIR: I hope I may be permitted some belated comments on Frank H. Westheimer's Priestley Medal address (C&EN, July 4, 1988, page 32) and the subsequent correspondence (C&EN, Aug. 22, 1988, page 3). Our copies of C&EN have been late in coming here [to Australia]. I believe David Wagger is right to state that science education must begin in the elementary grades; Westheimer discusses college education, but at this stage attitudes have already been formed and students have typed themselves as scientists or humanists. It is too late at college to try to change this. Juergen Braun makes the important point that current attitudes to science are a result of our cultural and social heritage. However, I do not think that any of the three commentators delves to the roots of the matter.

We have built up a distinction between science and the humanities that is purely an artificial distinction, derived from our cultural heritage as suggested by Braun. This division is of comparatively recent date, but perhaps having remoter links to medieval attitudes to learning. We do not need this separation of science from other learning, and other cultures do not seem to have introduced it. The success of Islamic science between 750 and 1100 AD was built on Quranic injunctions to acquire knowledge and on the absence of distinctions in value between aspects of that knowledge (for example, between science, technology, history, arts, and so forth). Why do we continue to cut learning in half?

It is better that we regard the world of learning as a continuum with the study of the natural world at one pole and the study of the works, thoughts, and aspirations of women and men at the other. Any real-world problem has scientific aspects mingled with human and social ones. An obvious example is the environmental debate around the use of pesticides in agriculture. No one can claim to be educated who cannot show some competence across this spectrum of learning. Science is not an entity separable from the generality of education.

The distinction currently given to science was brought to my attention clearly at my daughters' school, one which places a high priority on girls' getting equal opportunities with boys in math and science. The staff members were very apprehensive about introducing science into the primary school curriculum, afraid that it might be too early. My comment was that science is an integral part of education and begins at day one of school life. Once the education system identifies science as an alien and an add-on, then we have lost the battle. The defeat sustained by Westheimer at Harvard was an inevitable consequence of unrecorded battles lost in primary education.

Let us spread the notion of the universality of learning and rigorously reject all distinctions between branches. To educate, we must engender a curiosity in the natural and the human world, and teach the discipline of learning. There can be no distinction between scientist and nonscientist, or between humanist and nonhumanist. All educated persons are scientists and humanists.

Hugh D. Crone
Heidelberg, Australia

Breath of fresh air

SIR: Congratulations to my fellow chemists and chemical engineers! The letters by A. C. Nixon, Philip Sadtler, and David R. Fagerburg (C&EN, Nov. 21, 1988, page 2) are like a breath of fresh air after the dose of hysteria we have been receiving for years from the environmentalists.

Alfred N. Rogers
Pleasanton, Calif.

related activities is also up 14% to $1.8 billion, and funding for science and engineering education is up 11% to $190 million. Funding for the materials research division is up 18% to $135 million, for the chemistry division, 7% to $103 million, and for chemical and thermal systems engineering, 8% to $36 million. The NSF budget request allows for continued funding of the 11 science and technology centers announced last year, as well as initiation of a second competition for eight to 10 centers in fiscal 1990.

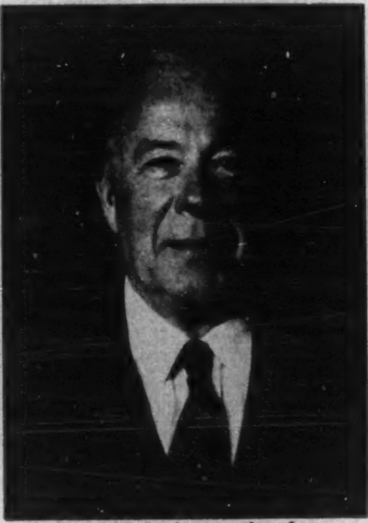
For the first time, this year's Special Analysis J of the R&D budget proposal breaks out the funding for programs that are supported by a number of agencies. It shows, for instance, that funding for the U.S. global change research program is slated to grow more than 40%, to $191 million, in fiscal 1990. Federal support for both low- and high-temperature superconductivity research is to increase 14% to $287 million. And support for technology transfer activities is to rise 5% to $510 million.

Janice Long

Chemical arms action urged at world meeting

A five-day conference on chemical weapons attended by nearly 150 nations ended last week in Paris with a vaguely worded communiqué condemning the use of chemical weapons, urging the swift completion of a stronger ban on such weapons, and reaffirming the powers of the United Nations Secretary-General to investigate charges of illicit use.

As one U.S. expert who asks not to be named says, it is a consensus document, and "the U.S. never expected precise language." The U.S. and its allies also never expected Soviet Foreign Minister Eduard A. Shevardnadze to announce that the U.S.S.R. would "immediately begin eliminating" its stock of chemical weapons, something the U.S. has already begun with its old, unitary weapons.



Shultz: abide by international norms

In his keynote address to the conference, Secretary of State George P. Shultz called on nations to renew their commitment to abide by "international norms relating to CW use." He also asked that nations that have not signed the 1925 Geneva Protocol do so. This protocol bans the use but not the production or possession of chemical arms. And Shultz urged that the UN Secretary-General's investigatory powers be "reinforced and enhanced."

The U.S. never explicitly stated what it meant by "enhanced" powers. And the final communiqué calls only for the "completion of the work undertaken to strengthen the efficiency of existing procedures." The Secretary-General has appointed a group of experts that is now developing suggestions to clarify and improve existing investigatory procedures.

During the conference, three countries—South Korea, North Korea, and Laos—signed the Geneva Protocol, bringing the number of signatory countries to 123. Others are expected to sign.

Though the final consensus document urges a speedy conclusion to ongoing talks in Geneva on a global, verifiable treaty banning the production, possession, and use of chemical weapons, the document fails to strongly address two other issues the U.S. raised. Shultz asked for measures to prevent the spread of chemical arms, especially to terrorist-supporting countries. Instead, the final document calls for countries to "exercise restraint and to act responsibly." The U.S. delegation also sought support for sanctions against countries using chemical arms in contravention of the 1925 protocol. Sanctions are addressed obliquely when the final document calls on the UN to take "appropriate and effective steps" under its charter.

Domestically, Sen. Don Nickles (R.-Okla.), who attended the conference with Shultz, says he will work for legislation imposing sanctions on U.S. and foreign firms contributing to chemical weapons proliferation. Last September Sen. Robert Dole (R.-Kan.) offered such a bill. Nickles says he will cosponsor a modified version of that bill, which Dole plans to reintroduce early this year.

The U.S. was not alone in not getting its way at the conference. A block of Arab delegates tried unsuccessfully to derail the conference by insisting that elimination of chemical arms be linked to the destruction of nuclear weapons. This was seen as a move against an alleged Israeli arsenal of nuclear weapons. Both the U.S. and U.S.S.R. objected to this move. After making the point in speech after speech, the Arabs dropped the ploy when it was agreed that the final document would call for "general and complete disarmament under effective international control."

Though it wasn't entirely successful, the U.S. was satisfied with the Paris exercise. As one close observer says, "80 foreign ministers [who attended the conference] are painfully aware of this issue now."

Lois Ember

European chemical growth to slow in 1989

Chemical production last year in Western Europe outstripped forecasts of early last year—in some cases, significantly so. That puts a special burden on forecasters trying to predict the performance of the industry this year.

Economists at the annual Business Outlook Conference of the

Chemical Industries Association in Britain last week were quick to point this out. Nonetheless, predict they did. The general consensus of U.K. economists is: Growth is slowing down, but is still good. This forecast agrees with the 1989 business outlook issued late last year by the European Council of Chemical Manufacturers Federations (CEFIC) in Brussels.

One of the keys to last year's performance, and to this year's continuation of that performance, is capacity constraints, says Richard Freeman, chief economist at ICI and chairman of the Chemical Industry Association's forecasting panel. "Fears of capacity constraints in 1988 seem to have been overstated," he adds. "This was the case not only in the U.K. but in other European countries as well."

The association's forecasting panel projects that production in 1989 is likely to be capacity-constrained "unless there is a marked slowdown in the rate of growth of demand," Freeman says. However, in making its predictions the panel assumes that supplies available in the U.K. will not be limited by capacity in the various chemical sectors. It also makes the assumption that average oil price will be $15 per barrel.

All told, the panel expects U.K. chemical production to grow 3% in 1989, following the 6 to 6.5% increase of 1988. Freeman terms the projected growth a "more sustainable level of increase." The panel also forecasts a 3.5% increase in chemical exports, down slightly from 5% in 1988, and a 4% rise in chemical imports, down from 7% in 1988.

British chemical growth to slow this year

Production, annual change	1988	1989
Plastics	13.0%	4.0%
Pharmaceuticals	8.0	4.5
Cosmetics, perfumes	6.5	2.5
Dyes	8.0	1.0
Organics	6.0	4.0
Inorganics	5.0	1.5
Paints	4.5	2.5
Detergents	3.0	2.0
Fibers	−4.0	0
Fertilizers	−8.0	0

Source: U.K. Chemical Industries Association

Chemical growth is also expected to slow down in the other Western European countries (C&EN, Dec. 12, 1988, page 34). For Western Europe as a whole, CEFIC projects a 3% rate of growth for chemical production, compared with just under 6% in 1988. "There is a strong consensus among European chemical industry forecasters about prospects for industrial production this year," Freeman says.

There is also a consensus that imports and exports will rise at a slower rate this year than in 1988 across Western Europe. CEFIC projects that chemical exports will increase 3% this year, compared with 6.5% last year. And it expects imports to grow only 2.5%, compared with 7% in 1988.

Costs for the U.K. chemical industry will rise in line with general inflation, the U.K. forecast panel assumes. It thus predicts that margins will be much the same as in 1988 or a little higher. "On this basis," says Freeman, "profits in the industry will show another healthy rise, but less so than the probably 10 to 15% in 1988."

The combination of strong demand and rising profits, he adds, is expected to bring another good year for investment in the U.K. industry: The U.K. group's survey of investment intentions indicates an increase of 8% in volume terms—a significant commitment, although a slight drop from the 12% rise in 1988.

Those predictions for the U.K. chemical industry track closely with the predictions of CEFIC for chemical industry investment throughout Western Europe. According to CEFIC, investment is expected to grow 6% this year, down from 9% in 1988. The relatively high level of investment in 1988, CEFIC notes in its economic outlook, was spent mainly on "extension and innovation," following the rationalization in previous years. This has resulted in higher productivity and improved processes and products throughout the industry.

Patricia Layman

Drug urinalysis can be very reliable

Labs can achieve nearly 100% accuracy in testing for illegal drugs in urine, a new study by the American Association for Clinical Chemistry (AACC) shows. "After today, inaccuracy should not be used as an argument against drug-testing programs," said toxicologist Christopher S. Frings last week as he released the results.

Thirty-one out of the estimated 150 commercial U.S. labs that carry out drug testing for employers participated in the study, according to Frings, who heads AACC's public issues committee. They were sent blind samples of urine containing cocaine, opiates, marijuana, amphetamines, or phencyclidine (PCP).

The labs correctly identified samples containing drugs 97% of the time, with no false positives. Various immunoassay methods were used for initial screenings, and samples that tested positive were further analyzed by gas chromatography-mass spectrometry.

"AACC will not suggest to you that all laboratories accepting employee drug-screening specimens are doing accurate work," Frings says. "But we maintain that laboratories that follow key operating procedures can demonstrate high accuracy in drug testing." AACC issued guidelines in 1987 to help employers choose and monitor a drug-testing lab (C&EN, August 3, 1987, page 26).

About 3% of private U.S. businesses have some sort of drug-testing program in place, according to a survey just released by the Department of Labor. But those companies employ about 20% of U.S. workers, as large companies are much more likely to have drug-testing programs than are small firms, the survey found.

However, such programs are being challenged regularly in the courts by labor unions and employee groups. Their lawyers argue that it is an invasion of privacy to force an employee to submit to a drug test without some reason to suspect he or she has used illegal drugs. Decisions will be rendered by June in two such cases now being considered by the U.S. Supreme Court.

Pamela Zurer

Chemical Industry R&D Spending To Increase Moderately

Ten major chemical producers plan 9% hike in research expenditures this year, translating to more than 7% in constant-dollar terms

Marc S. Reisch,
C&EN Northeast News Bureau

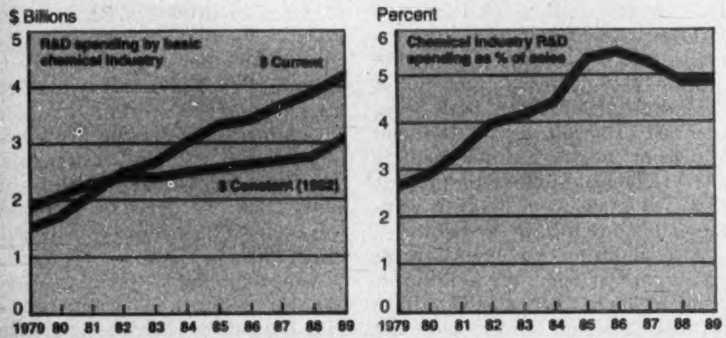
Major U.S. chemical and diversified companies plan a moderate increase in research and development spending in 1989, according to a preliminary survey by C&EN. The survey indicates that R&D spending for 10 companies that responded will rise 9% from last year. That is up from a 7% increase by the same 10 companies in 1988 compared with 1987.

The 9% increase found by C&EN's survey is in marked contrast to the 3.4% increase that Battelle Columbus Laboratories forecasts for all R&D spending (C&EN, Jan. 9, page 23). Battelle projects that total R&D spending in the U.S. will reach $129.2 billion in 1989. However, Battelle admits that industrial R&D spending, comprising about half of total R&D spending, will rise faster (4.5%) than government spending.

Part of the increased spending will be absorbed by inflation. Battelle forecasts a real increase in R&D expenditures of about 2%. Thus Battelle's forecast for 1989 R&D inflation is 1.4%. By contrast, last year Battelle predicted 1988 R&D inflation of about 4.5%. Factoring in Battelle's R&D-inflation forecast for 1989, the 10 chemical producers surveyed by C&EN will increase real R&D spending 7.6% in 1989.

C&EN's survey this year, as usual, does not include Du Pont. If that company's increase in R&D spending were to differ significantly from the 10 companies that responded to the survey, the final industry spending estimates could be drastically altered. In 1987, for instance, Du Pont spent $1.2 billion on R&D, excluding that for the former Conoco operations. In that year, its spending accounted for more than 33% of the total spent by the 12 chemical producers included in the survey.

R&D spending will rise modestly in 1989 . . . **. . . and will remain level as percent of company sales**



Note: For companies listed on page 16. Sources: C&EN surveys and estimates, Battelle Columbus Laboratories

Also missing in this year's survey is Hercules. A company spokesman says that Hercules is altering its R&D accounting procedures so that its European operations report in their R&D figures coincident with U.S. R&D spending estimates.

A planned emphasis this year on certain growth categories revealed in a survey of R&D directors accounts in part for the good increase in 1989 R&D expenditures for the 10 chemical producers C&EN surveyed. The R&D directors survey was conducted by Flad Associates, a Madison, Wis.-based firm specializing in laboratory design and construction. The survey, released in September 1988, asked respondents to anticipate capital spending on physical plant and equipment dedicated to R&D. Results show that for the period 1987 to 1989, expenditures would grow fastest for R&D facilities for industrial organic and inorganic chemicals, miscellaneous chemical products, drugs and related products, and rubber and plastic products.

The survey, with sponsorship by the University of Wisconsin and with assistance from the National Science Foundation, the Industrial Research Institute, and *Research & Development* magazine, anticipates increased research emphasis on categories essential to the 10 chemical producers included in C&EN's survey.

Another factor accounting in part for a higher real increase in R&D spending for the 10 companies compared with the very modest level of increase for all industry that Battelle predicts is the outstanding sales and earnings profile of these 10 companies and indeed for the industry as a whole over the past year. C&EN's survey of 30 major chemical firms (C&EN, Nov. 14, 1988, page 24) showed that sales through the third

Eli Lilly and Arco will post biggest gains in R&D spending

$ Millions	Planned 1989	Actual 1988	Planned 1988	1987	1986	1985	1984	1983	Change from previous year 1989	Change from previous year 1988	R&D spending as % of sales 1988	R&D spending as % of sales 1987
CHEMICAL COMPANIES												
Air Products[a]	$ 72	$ 72	$ 67	$ 57	$ 61	$ 51	$ 44	$ 40	0%	26.3%	2.9%	2.7%
American Cyanamid	385	360	356	314	278	251	232	208	6.9	14.6	7.5	7.5
Dow Chemical	850	760	720	670	605	547	507	492	11.8	13.4	4.9	5.0
Du Pont[b]	na	na	na	1223	1156	1144	1097	966	na	na	na	6.9
Ethyl	58	58	52	50	47	47	40	39	0	16.0	2.9	2.9
W. R. Grace	132	118	120	107	94	92	81	73	11.9	10.3	2.3	2.4
Hercules	na	na	76	74	71	76	72	74	na	na	na	2.7
Monsanto	615	590	538	615	596	470	370	290	4.2	−4.1	6.7	8.1
Olin	65	56	60	62	56	53	52	49	16.1	−9.7	2.5	3.2
PPG Industries	250	225	250	227	204	176	150	127	11.1	−0.9	3.8	4.4
Rohm & Haas	185	163	150	142	133	124	109	100	13.5	14.8	6.4	6.4
Union Carbide	193	166	175	159	148	275	265	245	16.3	4.4	2.1	2.3
TOTAL	**$2805**	**$2568**	**$2488**	**$3700**	**$3449**	**$3306**	**$3019**	**$2703**			**4.5%**	**5.3%**
ANNUAL CHANGE[c]	**9%**	**7%**		**7%**	**4%**	**10%**	**12%**	**8%**				
DIVERSIFIED COMPANIES												
Allied-Signal[d]	600	600	670	400	360	298	258	245	0	50.0	4.7	3.6
Arco Chemical	44	37	na	26	30	29	29	na	18.9	42.3	1.6	1.3
Eli Lilly	600	500	500	466	427	370	341	294	20.0	7.3	11.9	12.8
FMC	na	na	134	132	146	149	121	102	na	na	na	4.2
Merck & Co.	na	650	na	566	480	426	393	353	na	14.8	11.2	11.2
Morton Thiokol[d,e]	52	45	43	40	38	34	28	21	15.6	12.5	2.0	2.0
SmithKline Beckman	na	500	na	424	377	310	279	265	na	17.9	10.0	9.8
TOTAL	**$1296**	**$2332**	**$1347**	**$2054**	**$1858**	**$1616**	**$1449**	**$1283**			**7.2%**	**6.6%**
ANNUAL CHANGE[c]	**10%**	**21%**		**11%**	**15%**	**12%**	**11%**	**16%**				

a For fiscal year ended Sept. 30. b All figures exclude Conoco. c For those companies reporting. d Includes all company-financed R&D, but excludes contract R&D. e Fiscal year ended June 30. na = not available.

quarter of 1988 were 18% ahead of the previous year's first nine months, and earnings for the group were ahead by 75%. Given that sensational performance, management can afford to shore up their companies' R&D effort.

This year's survey conservatively estimates that the average increase in sales was 15% for the 10 companies that reported 1988 R&D figures. As a result, R&D spending as a percentage of sales decreased to 4.5% in 1988 compared with 5.3% in 1987. Part of the reason may be that sales growth for the chemical industry was better in 1988 than had been anticipated when 1988 R&D spending plans were put into place. Based on spending plans of the 10 companies in the survey, 1989 R&D spending as a percentage of sales will probably remain about the same as in 1988.

The biggest increase in R&D spending for 1989 is planned by Union Carbide, whose spending is slated to rise 16.3% to $193 million. The 1989 estimate excludes Carbide's catalysts business, which was combined with Allied-Signal's UOP subsidiary in a joint venture formed in August 1988. The planned 1989 increase follows a 4.4% increase the year before.

The second largest R&D increase in 1989 is planned by Olin, which expects to increase R&D funding 16.1% to $65 million. That increase follows a decline of 9.7% the year before when Olin says it spent $56 million. A company spokesman says that the 1988 decline both from planned expenditures for the year and from the $62 million spent in 1987 reflect a number of projects that had gone from R&D to commercialization during the year.

Also planning a double-digit increase in 1989 spending is Rohm & Haas. It plans to spend $185 million on R&D this year, up 14% over last year's level. The increase follows a 15% increase in R&D spending in 1988, when the company figures it actually spent $163 million. Rohm & Haas spends a consistently high percentage of sales on R&D; in both 1988 and 1987 it spent 6.4% of sales on R&D.

Also planning to boost its R&D spending more than in 1988 is W. R. Grace, with a 12% increase this year to $132 million. Last year's increase was 10%. Grace says it actually spent $118 million in 1988 on R&D.

Dow Chemical also is planning a considerable boost in its 1989 R&D expenditures. The company predicts it will spend $850 million this year, a 12% increase over the $760 million it gives as its best estimate at this point for its R&D spending in 1988. That 1988 level of spending was itself a 13% increase over spending in 1987.

Also increasing its spending above the average for the 10 companies is PPG Industries, which estimates its 1989 R&D spending at $250 million, up 11% from 1988. Because the company's actual 1988 R&D spending fell $25 million short of its planned $250 million expenditures for the year, its R&D spending in 1988 declined a marginal 0.9%.

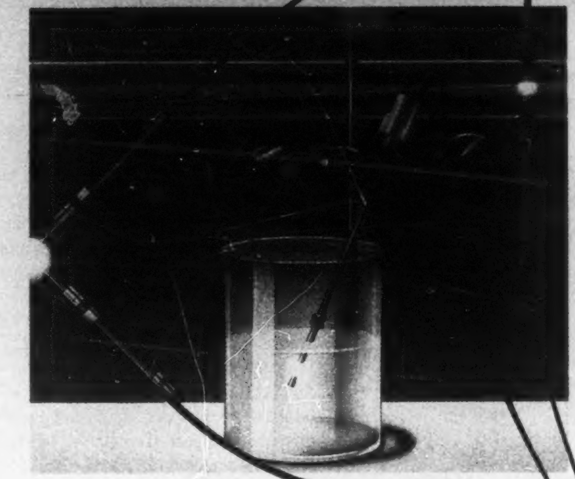
Only two of the 10 companies reported a spending increase lower than the 9% average increase for the group. American Cyanamid plans to increase expenditures 7% to an estimated $385 million. In 1988 it spent $360 million, up 15% from 1987. Despite the low rate of increase for 1989, Cyanamid's R&D spending as a percentage of sales, at 7.5% in both 1987 and 1988, has been consistently higher than for most other companies in the survey. No other company beat that figure in 1988 and only Monsanto reported a higher percentage, 8.1%, in 1987.

For its part, Monsanto predicts 1989 R&D expenditures that will keep its investment in the future at a rate slightly better than the rate of inflation. Monsanto says it will spend $615 million on R&D in 1989, only 4% ahead of 1988, when it spent $590 million. The lower 1988 R&D figure compared with 1987 pulled Monsanto's R&D spending as a percentage of sales down to 6.7%.

Ethyl and Air Products predicted no increase in their 1989 R&D spending. Ethyl, however, spent more in 1988 than it originally anticipated, pushing its R&D spending up 16%. Air Products says that 1989 spending will remain level with 1988 as the company refocuses its efforts following a 26% expansion in R&D expenditures in 1988.

Among diversified manufacturers, four companies responding to the survey—Allied-Signal, Arco Chemical, Eli Lilly, and Morton Thiokol—plan to increase their R&D budgets an average of 10% in 1989. Their figures include internally generated R&D contracts only and not government contracts.

As in last year's survey (C&EN, Jan. 18, 1988, page 9), the only pharmaceutical manufacturer that could provide an estimate of its 1989 spending was Eli Lilly. The company estimates that it will spend about $600 million in 1989, up 20% over the previous year and higher than the 7% increase in 1988 over 1987 R&D expenditures. Merck and



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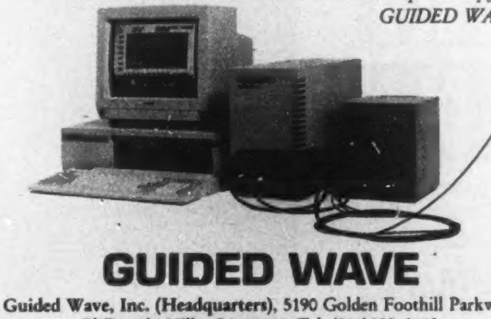

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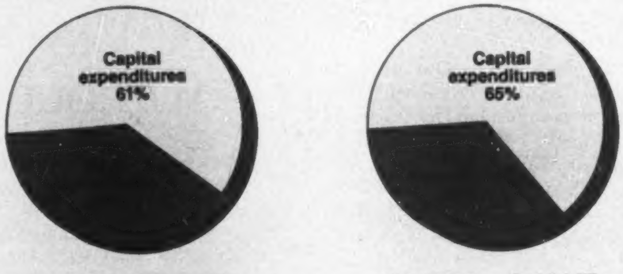
R&D declines as percent of future-oriented spending

After stabilizing over the previous two years, R&D expenditures as a percentage of future-oriented spending (capital expenditures plus R&D expenditures) have declined, according to figures supplied by the 12 major chemical producers C&EN contacted for its survey and by C&EN estimates.

In 1988, the R&D portion accounted for 35% of a total $11.2 billion in future-oriented spending, marking a 4% decrease in the R&D share of the total compared with 1987. In 1987 R&D accounted for 39% of a total $9.47 billion of future-oriented spending. The spread between 1988 and 1986 is an even higher 4.9%. In that year R&D spending accounted for nearly 40% of a total $8.85 billion in future-oriented spending.

The reason is that capital expenditures, fueled by increased commodity demands and higher prices, have increased at a faster pace than R&D. Eleven companies responding to C&EN's 1989 capital expenditure survey (C&EN, Dec. 19, 1988, page 10) reported capital expenditures in 1988 increased 31% from 1987. The rate of increase of R&D expenditures for 10 of the same eleven companies in 1988 was 7%.



Total 1987 = $9.47 billion

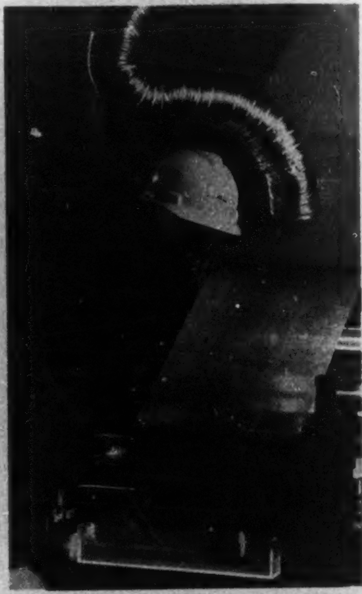
Total 1988 = $11.2 billion

Note: For companies listed on page 16. Source: C&EN surveys and estimates

SmithKline Beckman report they had spent $650 million and $500 million, respectively, in 1988, marking 15% and 18% increases, respectively. The pharmaceutical manufacturers as a group consistently spend the highest percentage of sales on R&D. Of the three covered here, Eli Lilly spends the most—an estimated 12% of sales in 1988 and 13% in 1987.

The second largest increase for R&D spending among the diversified manufacturers in 1989 was registered by Arco Chemical, which plans to increase spending 19% to $44 million. The increase follows a 42% increase in R&D spending in 1988 to $37 million.

Morton Thiokol reports it plans a 16% increase in 1989 R&D spending to $52 million after a 13% increase in 1988 to $45 million. Only Allied-Signal says it has no plans to increase R&D spending levels in 1989 beyond what it actually spent in 1988. □



Air Products researcher tests emulsion formulation for pressure-sensitive adhesives market

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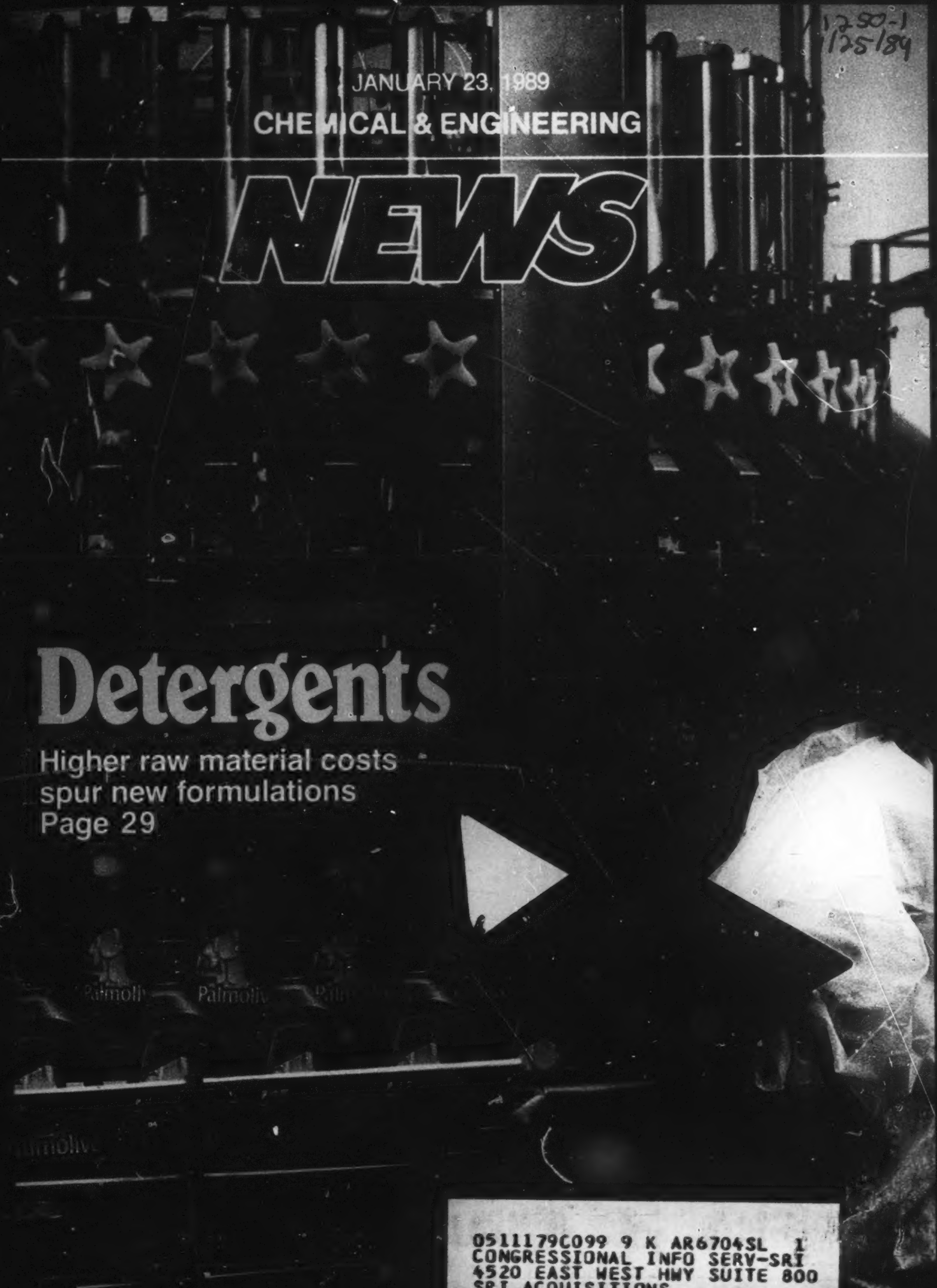
JANUARY 23, 1989

CHEMICAL & ENGINEERING NEWS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Detergents

Higher raw material costs spur new formulations
Page 29

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CHEMICAL & ENGINEERING

NEWS

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JANUARY 23, 1989

News of the Week

- **OSHA sets new exposure limits for hundreds of toxic and hazardous substances in its largest-ever workplace action.** Page 4
- **Pharmaceutical Manufacturers Association urges moves that would speed the FDA approval process for new drugs.** Page 5
- **Donald Kennedy, keynoter at annual meeting of the American Association for the Advancement of Science, sees alarming mistrust of science by general public.** Page 5
- **Presence of chemistry is strong at AAAS conference compared with past years.** Page 5
- **Also at AAAS meeting, Chinese scientists describe progress in and prospects for science and technology in China.** Page 6

Cover: Technician monitors bottles of automatic dishwasher detergent at Colgate-Palmolive's production facility in Kansas City, Kan. Photo by Richard Alcorn

Letters 2

Concentrates

Business 7
Government 15
Science/Technology 18

The Departments

Software/Database Update 26
ACS Focus 56
Newscripts 76

Business

Six executives purchase the world's only *p*-methylstyrene plant from their former employer Hoechst Celanese. **Page 13**

Study details problems that are hindering growth of the Soviet chemical industry. **Page 14**

Government

Scientific and technical community awaits George Bush's selection of a Presidential science adviser with hopeful anticipation. **Page 16**

Science

Protein that regulates the mercuric ion resistance genes of *Escherichia coli* exerts control by interaction with the metal ion, DNA, and RNA polymerase. **Page 19**

Education

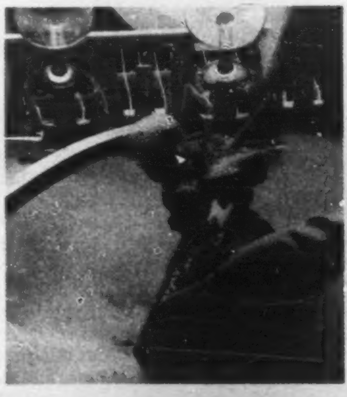
Workshop on undergraduate education in chemistry calls for more NSF support for chemical education. **Page 25**

Books

Small-quantity generators of hazardous waste can benefit from book that interprets morass of regulations. **Page 50**

ACS News

ACS may once again offer professional liability coverage, provided enough members apply to make the plan viable. **Page 58**



Product Report

More detergent makers are turning to new formulations in effort to maintain cost-performance levels of their products in face of rising raw material prices. Page 29

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LETTERS

Radiation epidemiology, extrapolation, and opinion

SIR: John W. Gofman asserts (C&EN, Sept. 26, page 74) that "the linear, nothreshold model of cancer induction by ionizing radiation may underestimate cancer risk, but not overstate it—contrary to" observations by R. J. Hickey (C&EN, May 23, page 2). Gofman adds that human epidemiological evidence "is the final reality check on hypotheses" and that "excess cancer occurs in human populations even from the slowest and lowest possible rates of delivery." Previously, Gofman stated [*Nuclear News*, **25**(13), 20 (1982)] that "scientifically it is thoroughly reasonable to say that cancer and leukemia induction by radiation is proportional to dose right down to the lowest conceivable doses." Such a position rejects the well-established biophysical phenomenon of radiation hormesis, which has been reported in depth by T. D. Luckey ["Physiological Benefits from Low Levels of Ionizing Radiation," *Health Phys.*, **43,** 771 (1982); "Hormesis from Ionizing Radiation," ibid., **46,** 705 (1984); "Hormesis bei Krebsinduktion durch radioaktive Strahlung hoher Ionizationsdichte," *Z. Phys. Med. Baln. Med. Klim.* (Sonderhelf 1), **13,** 11 (1984); "Beneficial Physiologic Effects of Ionizing Radiation," Leppin, W., et al., editors, "Die Hypothesen im Strahlenschutz," Georg Thieme Verlag, Stuttgart, page 184 (1985)].

Human radiation epidemiology reports imply health benefits from low-level radiation [for example, Hickey, R. J., Bowers, E. J., et al., "Low-Level Ionizing Radiation and Human Mortality: Multiregional Epidemiological Studies. A preliminary report," *Health Phys.*, **40,** 625 (1981); "Ionizing Radiation and Human Mortality: Multivariate Analysis of U.S. State Data," *Am. J. Phys. Anthropol.*, **54,** 233 (1981); "Radiation Hormesis, Public Health, and Public Policy: a Commentary," *Health Phys.*, **44,** 207 (1983)]. H. F. Henry noted ["Is All Nuclear Radiation Harmful?" *Health Phys.*, **43,** 767 (1982)] that he had commented earlier ["Is All Nuclear Radiation Harmful?" *J. Am. Med. Assoc.*, **176,** 671 (1961)] on health benefits of low-level radiation. Other aspects of the controversy were reported by R. J. Hickey, E. J. Bowers, and I. E. Allen ["TMI Psychological Impact," *Nuclear News*, **25**(7), 28 (1982); "Creative Statistics," ibid., **25**(10), 25 (1982); "Statistical Fantasy," ibid., **25**(14), 49 (1982)]. See also Hoffer, P. B., Gottschalk, A., Zaret, B. L., editors, "The Year Book of Nuclear Medicine—1984," Year Book Medical Publishers, Chicago, page 199 (1984). The controversy was also discussed in "Risks Associated with Exposure to Radiation: Science, Pseudoscience, and Opinion," *Health Phys.*, **49,** 949 (1985); in "Radiation Protective Effect of Bacterial Endotoxins: Nonspecific Immunity," *Health Phys.*, **49,** 1013 (1985); in "Health Benefits from Low-Level Ionizing Radiation: Radiation Hormesis and the Question of Stimulation of Immunological Efficiency," *Z. Phys. Med. Baln. Med. Klim.* (Sonderheft 1), **17,** 8 (1988); and in "Cigarettes, Rn, Cancer, and Health Physics," *Health Phys.*, **55,** 821 (Nov. 1988). Extensive observed evidence contradicts Gofman's allegations.

Reports presented at the International Symposium on Biological and Therapeutical Effects of Radon, held in Bad Hofgastein, Austria, October 1987, have been published. Examples are Deetjen, P., "Biologische und Therapeutische Effekte von Radon," *Z. Phys. Med. Baln. Med. Klim.* (Sonderheft 1), **17,** 5 (1988); Andrejev, S. V., "Über einen Möglichen Wirkungs Mechanismus der Thermalstollen-Behandlung in Böckstein (Österreich)," ibid., **17, 54** (1988); Bogoljubov, V. M., "The Clinical Aspects of Radon Therapy," ibid., **17,** 59 (1988); Morinaga, H., "Medical Experiences in the Japanese Radon Spa, Misasa," ibid., **17,** 67 (1988).

Insofar as I am aware, the 1987 Bad Hofgastein symposium and the findings have not been reported in any newspaper or technical news journal in the U.S. Why? Among European press reports were Mayrhofer, F., "Die Wohltätigkeit des Edelgases Radon," *Salzburger Nachrichten*, Oct. 10, 1987, and "Zur modernen Radontherapie," *Wiener Zeitung* (Vienna), Nov. 27, 1987.

P. Deetjen, of the Research Institute Gastein-Tauernregion, Badgastein, Austria, has issued an English language pamphlet on "Scientific Principles of the Health Treatments in Badgastein," 3rd edition, 1984, 14 pages. This and other publications regarding radon health and vacation resorts and spas in Austria may be obtained from Kurdirektor Joseph J. Flatscher, Kurverwaltung Badgastein, Haus Austria, A-5640 Badgastein, Austria.

In view of the controversy regarding health effects of low-level ionizing radiation, including propaganda, it is enlightening to examine the published Garland Lecture of E. W. Webster, "On the Question of Cancer Induction by Small X-Ray Doses," *Am. J. Roentgenology*, **137,** 647 (1981). He states, "There is no proven body of fact that establishes an increase in human cancer after low doses of X or gamma radiation such as those received environmentally, occupationally, or from medical diagnostic procedures; that is, radiation levels below about 10 rad (0.1 Gy)."

Tough problems hinder Soviet chemical growth

The U.S.S.R. is among the world's top producers of chemicals and chemical products. In 1986, for example, it led the world in output of chemical fertilizers, synthetic rubber, and ammonia, and was one of the leaders in plastics, sulfuric acid, and sodium hydroxide production. Chemical output has grown much faster than that of Soviet industry overall.

And yet, says a new study, as with the rest of Soviet industry, a variety of tenacious problems is hindering growth of the chemical sector and preventing it from reaching its potential. These problems include technological backwardness, difficulties in assimilating new technology, delays and cost overruns in plant construction, overly rigid central planning, poor product quality, irrational pricing, supply shortages of raw and intermediate materials, excessive managerial conservatism, and insufficient skilled labor.

In response, the Soviets have launched a comprehensive program for "chemicalization" of their economy by the year 2000. The program calls for growth of 30 to 32% in chemical output during the current five-year plan (1986–90), with investment slated to rise 50%. Among the fastest growing sectors are to be plastics (up 36%), man-made fibers (33%), pesticides (30%), and mineral fertilizers (26%), with pharmaceuticals and paints and lacquers also targeted for rapid growth.

However, the study notes, relatively weak overall economic growth in three of the past four years and a hard-currency crunch (due, in part, to lower hard-currency revenues from oil exports) have delayed construction of many new Soviet chemical facilities, especially those bought from the West. The Soviets have shifted emphasis recently to joint ventures with Western firms, rather than the massive turnkey plant contracts they signed with Western firms in the 1970s and 1980s.

Chemical exports to nonsocialist countries also are disappointing, as the Soviets suffer from a squeeze on both cost and revenue sides. Meanwhile, chemical imports from nonsocialist countries are rising rapidly. And, contrary to the five-year plan goals, investment in the chemical and petrochemical branches is stagnating.

Pharmaceuticals lead growth of Soviet chemical industry

Growth in gross output	1987	1986	1985	1984	1983	1982	1981
ALL INDUSTRY	4.0%	4.7%	3.9%	4.0%	4.2%	3.3%	3.4%
CHEMICAL AND PETROCHEMICAL INDUSTRY, TOTAL	4.4	5.8	5.3	5.2	5.9	3.0	5.5
CHEMICALS	5.0	7.1	5.3	5.6	6.8	3.8	6.7
Mining chemicals	4.6	7.5	5.7	4.3	5.0	0	4.8
Basic chemicals	4.9	6.8	6.1	4.6	8.1	4.0	7.3
Man-made fibers	2.9	7.7	1.7	5.0	8.5	4.0	5.5
Plastics, synthetic resins	5.1	9.6	5.9	10.3	5.9	−1.9	3.5
Paints, varnishes	4.8	3.8	4.0	6.0	4.4	1.3	4.7
Synthetic dyes	3.8	6.3	5.9	4.2	4.4	2.5	5.2
Pharmaceuticals	6.6	7.9	7.6	7.6	6.1	6.9	7.4
PETROCHEMICALS	2.5	3.4	4.0	4.1	2.8	2.4	3.0
Basic organic synthesis products	2.1	8.1	8.4	7.9	8.1	3.5	2.7
Tires	3.4	2.7	2.8	2.8	1.9	3.5	3.1
Rubber, asbestos	1.6	3.8	5.0	3.1	3.2	3.8	1.1
MINERAL FERTILIZERS (100% active substance)	4.6	4.3	8.0	3.5	11.2	3.0	4.7

Source: PlanEcon Inc. based on official Soviet figures

The comprehensive 222-page study on Soviet chemical production, trade, and investment was prepared by PlanEcon Inc., a Washington, D.C.-based firm specializing in research on the Soviet and East European economies. Selling for $2500, the study will appear each fall.

PlanEcon is also involved in an effort to inform U.S. chemical firms about the opportunities opened by glasnost and perestroika—the new Soviet policies of openness and restructuring. The Chemical Manufacturers Association and PlanEcon will cosponsor a conference in Washington, D.C., in March on Soviet chemical and petrochemical production and trade, on prospects for chemical equipment and process imports, and on joint ventures. PlanEcon research director Jan Vanous says U.S. firms are likely to find greater opportunities in chemicals and petrochemicals than in other sectors.

Soviet chemical exports to nonsocialist countries are one of the major disappointments pictured in the study. In 1987, such exports totaled just $1.25 million, up only 8.6% from 1980. The Soviets continue to export mainly basic, low-value-added products rather than moving, as planned, into specialty, high-value-added products, such as dyes, paints, explosives, photographic products, pesticides, and rubber products.

Unlike Western petrochemical producers, who are enjoying a boom based on low world feedstock prices, the Soviets are taking a beating on exports of bulk petrochemicals and products based on oil and gas, such as ammonia and urea. This is because, insulated from world prices, the Soviets have faced steadily rising domestic oil and gas costs, but have had to cope with falling prices on the world market for the final products. As a result, Soviet exports of ammonia and urea based on natural gas have plummeted from 51% of nonsocialist exports in 1981 to about 23% in 1987.

As for imports, the study says imports of chemicals and fertilizers from nonsocialist countries will soar 12% a year in 1988–92. This will furnish opportunities to supply high-priority Soviet needs for plastics, pesticides, and other materials.

Richard Seltzer

Industrial detergents (left) frequently contain materials found in household cleaners; a major building block in dishwasher detergents (below) is linear alkylbenzene

Higher Costs Spur New Detergent Formulations

Bruce F. Greek, C&EN Houston, and
Patricia L. Layman, C&EN London

Reformulation is getting more emphasis in the detergent industry than it has in several years. Increased raw material costs and detergent makers' reluctance to pass on those costs to consumers have led to subtle, yet significant, changes in how much of what goes into powder, liquid, and bar soaps and detergents.

By changing formulations in these significant and subtle ways, detergent makers and marketers are trying to improve cost/performance characteristics of their cleaning products. Generally, formulations have became more complex as a result of these efforts to enhance performance, specifically to impart greater multifunctionality to detergent products while keeping costs down.

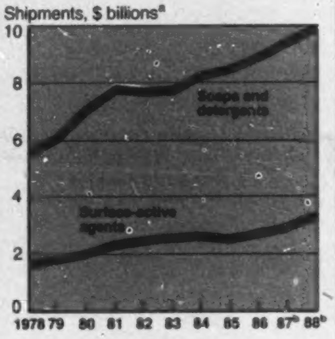
Detergent producers choose from a growing number of surfactants, builders, and other materials to provide the performance and aesthetic properties now expected from detergents. Costs of many of their raw materials have risen, with more increases forecast for later this year. However, material suppliers are offering improved products to maintain the cost/performance levels of detergent products in the extremely competitive retail markets for household cleaning and personal care products.

The detergent industry undergoes changes through evolution, as improved materials become available that meet the demands from consumers for such diverse performance characteristics as high cleaning efficiency and maximum convenience—all obtained at lowest possible cost. However, no revolutionary developments hit the detergent industry last year and none are expected this year.

One example of the trend in evolution in products offered by the detergent industry is the growth in sales of heavy-duty liquid detergents for household laundry. From about 15% of the total market in 1978, heavy-duty liquids have grown to more than 40% of the market this year.

Development of surfactants and other materials capable of giving a performance equal to that of the powdered products has been critical in this growth. Another critical factor has been development of formulating technology to make the components perform as desired (tak-

Value of soaps, surfactants about doubled in decade



a Products classified as soaps, cleaners, and toilet goods (SIC 284) produced by all industries. b Estimated.
Source: Department of Commerce

ing into account the frequent synergism between components). Consumer acceptance has grown significantly because of the convenience provided by single-dose application of liquid products. Many packages made for liquid detergents have a cap suitable for measuring the amount to add. The cap, designed to prevent residual detergent from running down the outside of the container, is known as the internally draining cap, one example of a packaging engineering development.

As the number of women working outside the home grew during the past decade, convenience took on much greater importance. Laundry methods involving a presoak, a washing, and a rinse, during which a fabric softener is added, no longer are acceptable. A surfactant, builder, bleach, softener, antistatic agents, and other performance chemicals now must be in the product added at the beginning of a wash, with no further attention given to the process until the clothes are moved to a dryer.

Demand for the multifunctional products has become firmly established in U.S. markets for many cleaning products other than household laundry detergents, and the trend is emerging in the other major regions of the world having large demand for detergents, especially Japan and Western Europe.

To keep bringing better products to market, the product formulators continually make decisions on which components they use, while taking into account the exacting relationship between cost and performance. Formulators try to develop particular niches for their products, while keeping the products as broadly applicable as possible. This allows maximum production volume for economies of scale.

Formulators now are receiving more help from their suppliers, who represent most of the major producers of chemicals. These suppliers are bringing more of the technical expertise used in making chemicals for many other industries into providing improved products for the detergent, cleaners, cosmetics, and related industries.

The application of chemical technology to cleaning preparations during the past generation has brought a huge boost to the materials available for use in the product. The American Chemical Society's manual of commercially available chemicals, *Chemcyclopedia*, includes more than 375 compounds and mixtures in the section on surfactants alone. Proprietary surfactants likely increase substantially the number used in commerce.

As the number of materials available for making cleaning products has mushroomed, so have the volume and the value of the materials. The value of shipments of soaps and detergents exceeded $10 billion for the first time in 1988, estimates Leo R. McIntyre of the Department of Commerce. That amount is 81% higher than the value of shipments in 1978. Even in terms of 1988 dollars, the value of last year's shipments was 7.3% ahead of that of 1987 (an estimated $9.4 billion).

The value of shipments of surfactants more than doubled between 1978 and 1988, McIntyre says, rising from $1.55 billion to almost $3.4 billion in 1988. The increase in value of shipments for surfactants during the past two years has been nearly twice as great as for all soaps and detergents, rising 25% between 1986 and 1988.

Close to 7 billion lb of formulated laundry detergents was used in the U.S. last year, mostly in households, McIntyre estimates. To reach this level, consumption has grown an average of more than 4% a year since 1980. In addition, use of automatic dishwasher detergents reached about 635 million lb last year.

The outlook for 1989 is for a 3.9% increase in the value of shipments of soaps and detergents, according

Surfactants fit generally into four classes

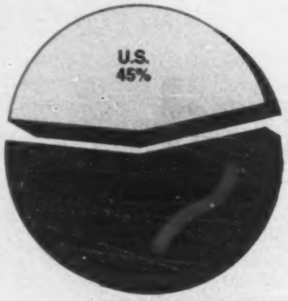
Anionics. Still at about 60% of U.S. surfactant production, anionics have slowly lost share of the increased market. The active detergency is in the large anion part of the molecule. However, the anion must be neutralized with an alkali before full detergency is obtained. Anionics also are the most widely used surfactants in formulated detergents. The largest volume anionics are based on alkylates of benzene and propylene trimer or tetramer.

Cationics. As implied by the name, the detergency in this class of compounds is in the cation. Because their efficiency in cleansing falls below many anionic and nonionic surfactants, they find less use in formulated detergents. The major uses are in specialized products that benefit from the presence of a surfactant. Most cationics are derivatives of amines.

Nonionics. The majority of nonionic surfactants are made by condensing a hydrophobe and ethylene oxide and then adding more ethylene oxide molecules to give a water-soluble product. The number of ethylene oxide molecules in the product surfactant can average 10 to 15. Several kinds of hydrophobes are used, such as fatty alcohols and acids, amines, and amides.

Amphoterics. This low-production class of surfactants has molecules that contain both an anionic and a cationic group. Depending on components of the molecule, amphoterics having various characteristics can be tailored into the final cleaning product or can provide fabric-softening properties. Examples of amphoterics are derivatives of imidazolines and betaines. Amphoterics' high cost limits their use.

U.S. leads world in surfactant use . . .



Total 1987 consumption = 14.5 billion lb[a]

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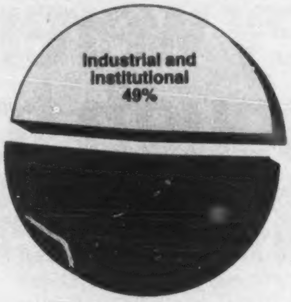

Total 1987 consumption = 14.5 billion lb[a]

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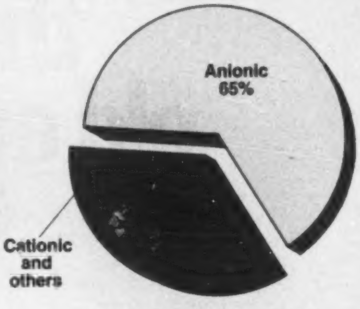


Total 1987 consumption = 14.5 billion lb[a]

[a] Includes soap.

to McIntyre. Longer-term prospects call for real growth (after inflation) to average 3% per year between 1989 and 1995. Sales of heavy-duty liquid laundry detergents are forecast to exceed sales of powdered laundry detergents by 1993.

Household cleaning products alone likely topped $9 billion in sales last year. In 1987, sales totaled $8.9 billion, up about 2.7% from 1986, according to a recent study by consultants Kline & Co. of Fairfield, N.J. Much of the growth in sales of household cleaning products comes from laundry detergents, particularly those in liquid form. Another fast-growing household cleaning product is liquid automatic dishwashing detergents, which reached about a quarter of the dollar sales volume for all automatic dishwashing detergents in 1987, according to the Kline study.

Further changes in demand for household cleaners are expected from diverse influences, such as shifts in population demographics, increased consumer demand for convenience in use of products, producer consolidation through acquisitions and divestitures, more proliferation of brands, and emergence of new segments in cleaners. Shifts in demographics include factors other than increases in number of women working, the Kline study shows—for instance, a growing proportion of single-person and older-person households. New segments in cleaners that are emerging include products that add convenience, such as the unitized dose packages of laundry detergents, cleaning wipes for bathroom cleaning, and cleaners specifically for microwave ovens.

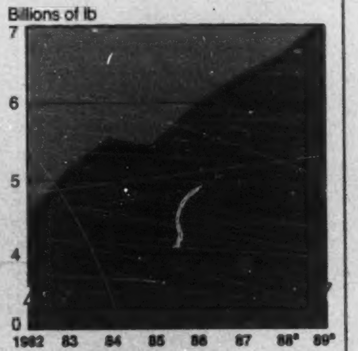
Besides household cleaners, two other major categories of cleaners are addressed by detergent producers—personal care products and industrial and institutional cleaning products. Personal care products may contain materials found in household cleaners, although their formulations generally are less complex. Industrial and institutional products also may be similar to household products, and may even be the same product.

Although the same materials generally may be used in cleaners, there is a wide variation in formulation, depending on the kind of cleaning and circumstances of the cleaning. Variations are especially notable in different regions of the world. Some products, such as personal care items, may be a surfactant and one or two other components. Others, such as laundry detergents, may contain 10 to 15 ingredients, some in concentrations ranging up to 50% of the total, and others in only a few parts per million. Excluding fillers and water, some of the components in cleaners are of major interest to the formulators as key performers, whereas others have minor roles.

Household cleaners, particularly laundry detergents, receive most of the attention in development activities because of the competitive nature of markets and because the large volume permits relatively better margins. Components of these cleaners fall into three major categories: surfactants, to remove dirt and other unwanted materials from clothes; builders, to treat the washwater to improve the efficiency of surfactants; and additives, which may include bleaches, bleach activators, antiredeposition agents, optical brighteners, antistatic agents, and fabric softeners.

Because of their importance, surfactants receive more development effort than any other components of cleaners. Soap, known for 4500 years but used mainly as a cosmetic for the first 3500 years, remains the

1989 output of surfactants could hit 7 billion lb



[a] Estimated. Sources: U.S. International Trade Commission, C&EN estimates

Household detergent formulations vary in U.S., Western Europe, and Japan

Component	Examples	Composition, %					
		U.S.		Western Europe		Japan	
		With builders	Without builders	With builders	Without builders	With builders	Without builders
HEAVY-DUTY POWDERED DETERGENTS							
Anionic surfactants	Alkylbenzene sulfonates	0–15%	0–20%	5–10%	5–10%	5–15%	5–15%
	Fatty alcohol sulfates	—	—	1–3	—	0–10	0–10
	Fatty alcohol ether sulfates	0–12	0–10	—	—	—	—
	Alpha-olefin sulfonates	—	—	—	—	0–15	0–15
Nonionic surfactants	Alkyl and nonylphenyl poly(ethylene glycol) ethers	0–17	0–17	3–11	3–6	0–2	0–2
Suds-controlling agents	Soaps, silicon oils, paraffins	0–1.0	0–0.6	0.1–3.5	0.1–3.5	1–3	1–3
Foam boosters	Fatty acid monoethanol amides	—	—	0–2	—	—	—
Chelators (builders)	Sodium tripolyphosphate	23–55	—	20–40	—	10–20	—
Ion exchangers	Zeolite 4A, poly(acrylic acids)	—	0–45	2–20	20–30	0–2	10–20
Alkalies	Sodium carbonate	3–22	10–35	0–15	5–10	5–20	5–20
Cobuilders	Sodium citrate, sodium nitrilotriacetate	—	—	0–4	0–4	—	—
Bleaching agents	Sodium perborate	0–5	0–5	10–25	20–25	0–5	0–5
Bleach activators	Tetraacetylethylenediamine	—	—	0–5	0–2	—	—
Bleach stabilizers	Ethylenediaminetetraacetate	—	—	0.2–0.5	0.2–0.5	—	—
Fabric softeners	Quaternary ammonium compounds	0–5	0–5	—	—	—	0–5
Antiredeposition agents	Cellulose ethers	0–0.5	0–0.5	0.5–1.5	0.5–1.5	0–2	0–2
Enzymes	Proteases, amylases	0–2.5	0–2.5	0.3–0.8	0.3–0.8	0–0.5	0–0.5
Optical brighteners	Stilbene derivatives	0.05–0.25	0.05–0.25	0.1–0.3	0.1–0.3	0.1–0.8	0.1–0.8
Anticorrosion agents	Sodium silicate	1–10	0–25	2–6	2–6	5–15	5–15
Fragrances		a	a	a	a	a	a
Dyes and blueing agents		a	a	a	a	a	a
Formulation aids		0–1.0	0–1.0	—	—	—	—
Fillers and water	Sodium sulfate	Balance	Balance	Balance	Balance	Balance	Balance
HEAVY-DUTY LIQUID DETERGENTS							
Anionic surfactants	Alkylbenzene sulfonates	5–17	0–10	5–7	10–15	5–15	—
	Fatty alcohol ether sulfates	0–15	0–12	—	—	5–10	15–25
	Soaps	0–14	—	—	10–15	10–20	—
Nonionic surfactants	Alkyl poly(ethylene glycol) ethers	5–11	15–35	2–5	10–15	4–10	10–35
Suds-controlling agents	Soaps	—	—	1–2	3–5	—	—
Foam boosters	Fatty acid alkanolamides	—	—	0–2	—	—	—
Enzymes	Proteases	0–1.6	0–2.3	0.3–0.5	0.6–0.8	0.1–0.5	0.2–0.8
Builders	Potassium diphosphate, sodium tripolyphosphate	—	—	20–25	—	—	—
	Sodium citrate, sodium silicate	6–12	—	—	0–3	3–7	—
Formulation aids	Xylene sulfonates, ethanol, propylene glycol	7–14	5–12	3–6	6–12	10–15	5–15
Optical brighteners	Stilbene derivatives	0.1–0.25	0.1–0.25	0.15–0.25	0.15–0.25	0.1–0.3	0.1–0.3
Stabilizers	Triethanolamine	—	—	—	1–3	1–3	1–5
Fabric softeners	Quaternary ammonium salts	0–2	0	—	—	—	—
Fragrances		a	a	a	a	a	a
Dyes		a	a	a	a	a	a
Water		Balance	Balance	Balance	Balance	Balance	Balance

a Component may be present in very small concentrations. Source: Henkel

most used surfactant today, despite the enormous development of synthetic surfactants during the past 40 years. However, soap has relatively few development efforts under way except in the improvement of purity and processing.

As a group, however, the synthetic materials far exceed soap in production volume. The development of synthetic surfactants came about because of soap's high sensitivity to water hardness and its tendency to leave unwanted waste products and an odor in clothes.

The synthetic surfactants and their formulated products—synthetic detergents—became available commercially in Germany in the late 1920s but didn't begin to sell in large volumes in developed countries until after World War II. The alkylation processes used to make high-octane components of aviation gasoline during World War II led to development of the branched chain alkylbenzene sulfonates. Then, synthetic detergents of many kinds were on their way. The first synthetics—fatty alcohol sulfates and

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have to do is call
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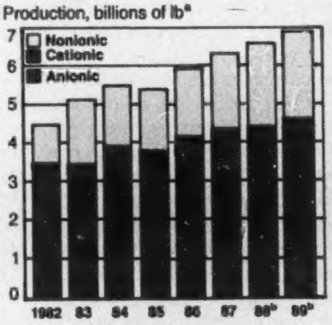
Nonionic and cationic surfactants show gains



a Excludes small quantity of amphoteric surfactants. b Estimated. Sources: U.S. International Trade Commission, C&EN estimates

derivatives made by reacting these alcohols with ethylene oxide—and the linear alkylbenzene sulfonates continue to be important in today's surfactant markets. Linear alkyl chains replaced branched chains to improve greatly biodegradability.

U.S. production of synthetic surfactants in 1989 likely will exceed 7 billion lb for the first time, up 6% from the estimated 6.6 billion lb produced last year. That growth would about match growth during both 1986 and 1987. Total production in 1987 was 6.27 billion lb, according to the U.S. International Trade Commission (ITC). More than 58% of U.S. production of surfactants in 1987 was anionics, ITC says. About 655 million lb, or 10% of production, was cationic surfactants, and the remainder was nonionics, except for a small quantity (33 million lb) of amphoteric surfactants. About 62% of production of surfactants was sold in 1987, having a value of more than $1.7 billion (the remainder was consumed captively).

Production of anionic types of surfactants grew very little in 1987, increasing only 13 million lb from 1986 to a total of 3.67 billion lb. Cationic surfactant output rose 33% from 1986 to 655 million lb in 1987 but has the smallest base of the three largest categories. Nonionic surfactant production rose 11% to 1.91 billion lb in 1987.

As in the past, the various lignin sulfonates held their position as the largest-volume anionic surfactants, but not by much, at more than 880 million lb. The various sulfuric acid esters and salts, which include numerous sulfated alcohols and ethers as the result of ethoxylation, had a total production of about 800 million lb. Alkylbenzene sulfonates (mostly dodecyl derivatives) ranked third, at more than 735 million lb.

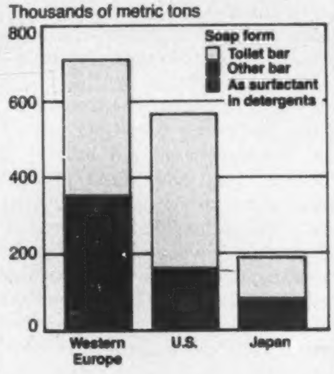
Nearly all cationic surfactants are amine or amide derivatives or are quaternary ammonium salts, with few individual compounds having significant production volume. The nonionics, at more than 800 million lb, are dominated by various ethoxylated linear alcohols, many of which are mixtures of alcohols before being ethoxylated. Benzenoid ethers, especially ethoxylated nonylphenol, accounted for more than 500 million lb of nonionics production in 1987. Various carboxylic acid esters, at more than 300 million lb, made up much of the remainder of nonionics production.

After soap, the most used surfactants in North America, Western Europe, and Japan are linear alkylbenzene sulfonates (LASs). According to estimates of West German detergent maker Henkel, 1987 consumption of LASs in those areas exceeded 2.15 billion lb. By far, the largest share of LASs consumed in the world is dodecylbenzene sulfonate, because that compound provides the best performance. Various other aromatic nuclei such as naphthalene, toluene, xylenes, and phenol are used in specialized products, and many other alkyl groups also may be used to make various surfactants.

LAS compounds compete with several other large-volume surfactants as one of the active components of cleaners. Their growth has varied during the 1980s as their cost and the cost of competing surfactants increased and decreased relative to each other. Currently, LAS demand appears to be growing more rapidly than in the recent past, because their cost has not increased so fast as the cost of competing alcohol sulfates, alcohol ether sulfates, alcohol ethoxylates, and other surfactants based on ethylene as the basic raw material. Benzene and propylene, basic raw materials for most linear alkylbenzenes, increased less in price last year than did ethylene, the price of which has more than doubled in just over a year. A part of the extensive reformulation of detergent products that began in 1988 and is expected to continue this year is the direct result of cost hikes of ethylene-based surfactants.

Often LASs are combined with other surfactants in a detergent formulation to give desired cost/performance. Included in the cost considerations are processing cost advantages, such as the ease of spray drying if a powdered product is being made. One of LASs' performance disadvantages that can offset their cost advantage is their greater sensitivity to water hardness than that of alcohol ether sulfates or some of the nonionic surfactants. Because sodium tripolyphosphate or other builders are seldom used in heavy-duty liquid detergent formulations to soften water, makers of these detergents have tended to use more alcohol ethoxylates than LASs. The more rapid shift toward liquid laundry detergents during the mid-1980s and an earlier increase in cost of LASs slowed growth in demand at that time. More recently, further declines in the use of phosphate builders have caused detergent formulators to increase surfactant concentrations. At the same time, the synergistic effect of LASs and alcohol ethyoxylates in cleaning performance became more widely recognized, increasing demand for LASs.

Toilet bars dominate soap use around the world



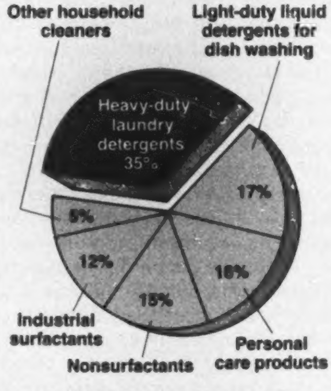
Source: Henkel

LASs consumption ranges across the many cleaning formulations because of their high cost/performance effectiveness. This property is behind the substantial growth of linear alkylbenzenes (LABs) forecast by Colin A. Houston & Associates, a consulting firm in Mamaroneck, N.Y. According to a recent study by the firm, worldwide demand for detergent alkylates, mostly LABs, will grow to 2.6 million metric tons by the year 2000, from 1.8 million metric tons in 1986. Most all of these alkylates become surfactants as a result of being sulfonated, and about 85% becomes a component of household cleaning products, primarily laundry detergents. Large developing countries such as India and China are fueling the growing global demand for LABs, according to Houston, whereas areas such as North America and Western Europe have mature markets with moderate growth expected.

LABs will continue to replace branched-chain alkylbenzenes (BABs) in surfactants throughout the world because of the poor biodegradability of BABs. Although North America and Western Europe changed from BABs to LABs about 25 years ago, other regions of the world began the switch very recently. Only in Latin America will BABs consumption increase during the next decade, according to the Houston study.

To meet demands, a rapid increase in capacity for LABs is under way in East bloc and Third World countries, Houston finds. Although LABs consumption in these countries will increase 800,000 metric tons by 2000, most of the intermediate will be supplied locally, tending to limit export opportunities for producers in industrially developed areas.

Laundry detergents take 35% of detergent alcohols



Total 1987 consumption = 680 million lb

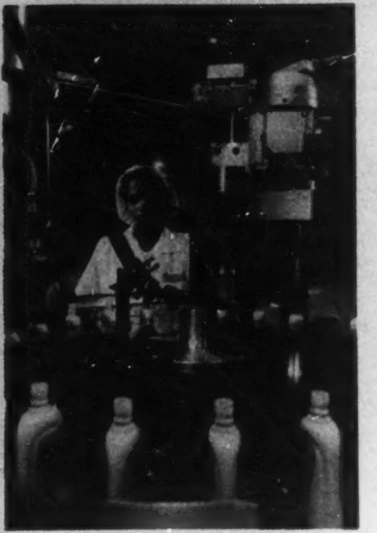
Source: Shell Chemical

In the U.S., both major producers of LABs—Monsanto and Vista Chemical—have expansions under way to add more than 150 million lb to annual capacity. These expansions are the result of above average growth in demand for LABs since 1985, in the 5 to 6% range, says Anthony J. Zoglio, Monsanto's business manager for detergents and surfactants. The demand growth has come from both the limits on phosphate builders in the U.S. and from the shift toward heavy-duty liquids for laundry use, both developments causing formulators to increase the concentration of surfactant in detergents. However, longer term, Zoglio expects demand to grow more slowly, at 3 to 4% per year, as supplies of ethylene improve when plants under construction begin operation, price increases of ethylene-based surfactants slow down, and reformulation toward more use of LASs in detergents also slows down.

Vista believes that LABs' growth will continue at more than 5% in 1989. The company increased its LAB capacity 45 million lb last year and will add another 60 million lb to capacity this year, bringing its total to 490 million lb. A part of Vista's Baltimore, Md., detergent alkylate capacity will be used for specialty alkylates used as lubricant additives.

Vista also makes detergent alcohols, the derivatives of which are competitors of LASs in detergent formulations for various end uses. Besides Vista, producers include Shell Chemical (the largest), Ethyl, Procter & Gamble, and others with small capacities. These alcohols generally fall in the range of C_{12} to C_{18}, either synthetic or natural. The synthetics are based on ethylene or on *n*-paraffins separated from petroleum. The natural alcohols are based on coconut and palm oils and on tallow.

The synthetic alcohols are produced by several processes. One



Detergents filling line at British Petroleum's Unza plant in Malaysia

group of processes is based on the reaction of carbon monoxide and hydrogen with linear olefins, either alpha or internal, in the presence of a catalyst. Linear olefins are made either from ethylene or are recovered from suitable petroleum fractions, such as a kerosine cut, using molecular sieves.

Another group of commercial processes to produce detergent alcohol involves reaction of triethylaluminum and ethylene (the Ziegler technology) to build longer-chain triethyl aluminums, oxidation to alkoxides, and subsequent hydration to alcohols and aluminum hydroxide. These processes produce very high fractions of even-numbered carbon chain length linear alcohols. The coproduct aluminum hydroxide is usually recovered and sold as the oxide or another salt.

Detergent alcohols are made from natural sources by using methanol to break the triglycerides in vegetable oils and tallow to give methyl esters of the fatty acids and the coproduct glycerin. The esters then are hydrogenated, using a copper-based catalyst, to the alcohols and methanol, which is recycled. The mixture of alcohols, which may include chain lengths ranging from C_6 to C_{20} and higher, is fractionated to remove impurities and to give cuts of alcohols with the desired chain lengths.

Supply of raw materials for making synthetic detergent alcohols will easily meet demands, as capacity expansions continue. For example, Shell Chemical has added 50 million lb-per-year capacity to its unit at Geismar, La., bringing capacity there to 700 million lb per year. At the same time, Shell raised its detergent alcohol capacity 50 million lb per year to 600 million lb per year. A second linear alpha-olefin unit is under construction for Shell at Geismar. This unit will have a capacity of 535 million lb per year plus substantial, but undisclosed, internal olefins capacity when it starts up this spring.

The alcohols, often ethoxylated or reacted with other compounds first, are converted to derivatives useful as surfactants largely by reaction with sulfur trioxide, chlorosulfonic acid, or oleum. The products then are neutralized with base, mainly sodium salts.

Between 80 and 90% of detergent alcohols are converted to surfactants. Four products—alcohol ethoxylates, alcohol sulfates, alcohol ether sulfates, and alkylglyceryl ether sulfonates—account for most of the surfactant uses, which include heavy-duty laundry detergents, light-duty liquid detergents (mostly for hand dishwashing), other household cleaners, various personal care products, and many institutional and industrial cleaners. Other derivatives of detergent alcohols may be used in detergent formulations, such as fabric softeners.

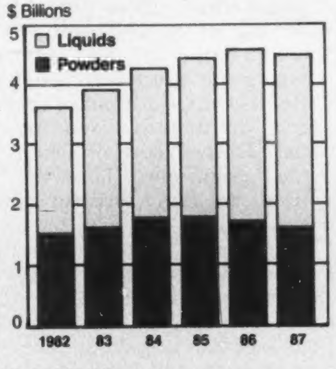
U.S. demand for surfactants based on detergent alcohols has grown about 3% annually between 1976 and 1986, says Jerry G. Moffett Jr., Shell Chemical's business manager for detergent products. While agreeing that the increased cost of ethylene-based surfactants has caused detergent manufacturers to reformulate to hold down cost increases, Moffett says that the total impact, as well as the longer-term impact, on these surfactants is as yet unclear.

Six surfactants account for most of market

Billions of lb	
Soap	3.25
Linear alkylbenzene sulfonates	2.15
Alcohol ethoxylates	1.05
Alkylphenol ethoxylates	0.85
Alcohol ether sulfates	0.75
Alcohol sulfates	0.55
TOTAL	8.60

Source: Henkel

Bulk of laundry detergent sales growth is in liquids



Source: Kline & Co.

Suppliers of materials for these surfactants have to counteract higher costs by offering better products. Shell Chemical, for example, has greatly increased the number of ethoxylates it makes, according to Moffett. Shell also has begun to offer grades of single-cut detergent alcohols such as C_{11}, C_{13}, and C_{15}.

In Western Europe, the shift to heavy-duty liquid laundry detergents has begun, but the share of the market is half or less than the share in the U.S. Some differences exist in detergent formulation in that region from the formulations used in the U.S. And Japan differs from both regions. Even so, many of the same kinds of surfactants are used in all three regions and are influenced by consumer demands that may differ from region to region.

The shift to heavy-duty liquid detergents, however, has caused a dramatic increase in surfactant concentration, according to René Carlotti, Shell's London-based business manager for detergents, higher olefins, and plasticizers. At this time, Carlotti says, ethoxylation capacity to make surfactants based on detergent alcohols is fully utilized in Western Europe, possibly limiting growth in the near term. However, Shell is adding capacity in the U.K. and

Spain; the unit in Spain is scheduled to go on stream in mid-1989. Other companies also are adding ethoxylation capacity in Western Europe.

The rise of heavy-duty liquid laundry detergents in Italy has been especially rapid, says Luciano Topi, commercial director of EniChem Augusta in Milan. This shift to liquid detergents in Western Europe is straining ethylene oxide supply, he adds. Ethylene supplies also are tight, and, although ethylene oxide for detergent products is a small part of the total ethylene market, the derivatives supply is limited.

In both the U.S. and Western Europe, the trend toward heavy-duty liquid detergents could cause some shift in choices made among the fast-growing detergent alcohol products to be used. Among the anionics, competition among LASs, alcohol sulfates, and alcohol ether sulfates could slow the growth of all, relative to the major nonionic compounds produced from detergent alcohols, alcohol ethoxylates. These compounds hold an edge because they are nonionic, a surfactant form that generally is unaffected by water hardness in performing cleaning functions. Since most liquid detergents do not contain phosphate builders to handle water hardness, alcohol ethoxylates and derivatives can have cost/performance values comparable to other alcohol surfactants.

Another advantage often cited for use of alcohol ethoxylates in formulated detergents is their ability to remove oily stains from fabrics. Although it's a widely debated view, some formulators believe the ethoxylates are better than anionics for washing garments that have high contents of synthetic fibers, especially polyesters, at low temperatures. The shift in demographics and life style in the U.S. has led to fewer dirty work clothes and fewer children's clothes in the laundry and more dress and athletic clothing containing body oil stains. That has caused formulators to partially substitute nonionic alcohol ethoxylates for LASs, spurring growth in demand. However, because alcohol ethoxylates remove body oils so well, they are seldom used in hand dishwashing or personal care products. The many industrial and institutional detergent uses of the ethoxylates also are helping growth.

Washing conditions influence detergent formulations

	Washing machines		
	U.S./Canada	Japan	Western Europe
	Agitator type	Impeller type	Drum type
Heating coils	No	No	Yes
Fabric load, kilograms	2–3	1–1.5	3–4
Wash liquor, liters	35–80	30–45	18–25
Total water consumption, regular heavy cycle, liters	140	150	120
Wash liquor ratio	1:15–1:30	1:20–1:30	1:5–1:25
Wash time, minutes	10–15	5–15	60–70 (90 °C) 20–30 (30 °C)
Wash, rinse, and spin time, minutes	20–35	15–35	100–120 (90 °C) 40–50 (30 °C)
Wash temperature, °C			
Hot	50	10–40	90
Warm	27–43	—	60
Cold	10–27	—	30–40
Water hardness (median), ppm $CaCO_3$	100	50	250
Automatic detergent addition	Mostly no	Mostly no	Dispenser
Recommended detergent dose			
Grams per liter[a]	1.5	1.3	8–10
Grams per kilogram of fabric	35–50	30–40	60–80
Peroxide bleach	b	b, c	b
Chlorine bleach	b	b, c	b, c
Drying process by automatic dryer	b	b, c	b, c

a In U.S./Canada and Japan without bleaching components. b May be commonly used. c Item considered less important. **Source:** Henkel

Few other nonionic surfactants are consumed in large quantities in household detergents, although some have large use in industrial detergents. Alkylphenol ethoxylates have wide industrial application; fatty amine oxides and fatty alkanolamides often are used in light-duty liquid detergents and in some personal care products such as foam stabilizers.

Cationic surfactants are used in laundry detergents mainly for special properties, such as providing a softening or an antistatic effect. Small quantities are used to obtain a synergistic effect with anionics. Cationics are used in many formulations for industrial and institutional cleansers, specialty emulsifiers, and germicides. Chemically, almost all are many types of amino compounds.

Regardless of type, surfactant performance depends on the quality of the water used, a fact known since cleaners were first invented. The process of lowering the surface tension of water and improving wettability of fabrics or surfaces falls to surfactants, but this process is hindered by water hardness—the concentration of calcium and magnesium ions in water. The ions may react with surfactants and other components of a cleaner to form products that precipitate and, in effect, leave the washed item less clean than expected. To handle water hardness, builders long have been added to detergent formulations. Currently, most builders used in detergents complex or chelate the unwanted calcium and magnesium, prevent redeposition of soil, help disperse and suspend dirt, and generally improve the efficiency of surfactants.

The largest quantity of material used in detergent formulations as builders, by far, is sodium tripolyphosphate (STPP). Other builders sometimes used include such inorganic compounds as soda ash, sodium silicates, other phosphate compounds, and various zeolites. Citric acid, sodium citrate, aminopolycarboxylic acids and salts, and certain acrylic polymers account for most of the rest of the builders used in household cleaners and in institutional and industrial cleaners consumed in the U.S. In Western Europe and in other regions, some sodium nitrilotriacetate is used as a builder and competes with STPP.

Despite bans on use and limitations on concentrations of phosphates in detergent formulations in various areas of the U.S. and other parts of the world, and despite growth in use of liquid laundry detergents without STPP, phosphate builders still dominate this category of components in formulated detergents and cleaners. Other builders are evaluated against STPP to determine their efficiency in detergent formulations.

Demand for STPP will decline 2 to 3% this year, according to Michael W. Berezo, Monsanto's business manager for builders and polyphosphates. The bans on phosphates in household detergents in various parts of the U.S. to reduce eutrophication (algae growth) in lakes and streams and the shift toward heavy-duty liquid laundry detergents that either don't contain builders or contain nonphosphate builders are causing the decline. Additional state bans are expected to further reduce demand for phosphate builders in powder laundry detergents.

Longer term, U.S. demand for phosphates in laundry detergents will remain unchanged at best over the next three years, says Lewis G. Furman, FMC's marketing manager for phosphorus chemicals. More likely, a decline of 5% or more may occur from 1988 levels unless bans on phosphate use are reversed.

Both Berezo and Furman agree that large markets remain for phosphate materials in detergent formulations of many kinds for the many uses other than heavy-duty laundry detergents. Monsanto, for example, has developed a special grade of material of medium density for use in making automatic dishwasher detergents, a market that is growing because of the increasing number of homes with automatic dishwashers, points out Berezo. FMC is working on phosphate systems for application to formulated liquid products for the various institutional and industrial cleaner markets, particularly commercial laundering, automatic dishwashing, and food service areas.

Three derivatives consume 81% of detergent alcohol

Total 1987 consumption = 680 million lb

Source: Shell Chemical

In the institutional and industrial market area, Monsanto offers tetrapotassium pyrophosphate (TKPP) as a highly soluble builder for use in commercial dishwashing detergents. The company notes that its sales of the compound increased 19% in 10 months of 1988. TKPP costs more than STPP, but is less soluble. To offset the cost factor, Monsanto also offers sodium trimetaphosphate, to which potassium hydroxide can be added by a formulator to get the sequestering qualities of STPP and the solubility of TKPP, Berezo says.

Other builders that are the only practical alternatives to phosphates also are used and various efforts are made to overcome their deficiencies. However, some of these builders also provide other desirable properties to formulated detergents so their use can further offset their deficiencies as builders. For example, soda ash will remove calcium ions from water by precipitation as the carbonate. But the calcium carbonate is difficult to keep in suspension and often redeposits on fabrics, giving a harsh feel and a grey tint to white clothes. It also dulls colors. But soda ash costs less than STPP. It also provides bulk in powder formulations and contributes to flow during detergent manufacture and packaging.

Sodium silicate provides alkalinity to the wash water, reduces corrosion in washing machines, aids in manufacturing (especially in spray drying), has a low cost, and provides bulk, but it does not react significantly with calcium ions in

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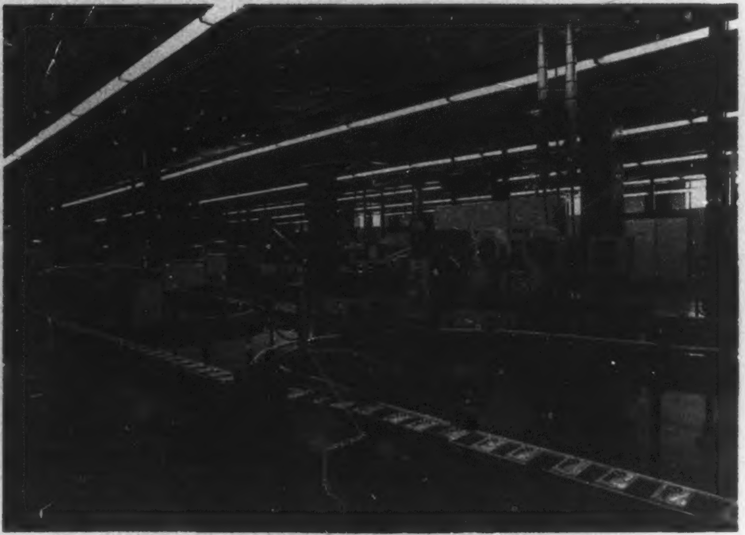


Lever's Hammond, Ind., plant turns out its Dove and Caress beauty bars

the water. It does contribute to deflocculation of soils and aids antiredeposition of soils and calcium precipitates. Therefore, sodium silicate and sodium carbonate often will be used together in powdered detergent formulations.

Zeolites (sodium aluminosilicates) as ion exchangers long have been found useful in detergent formulations in varying degrees. They have low solubility, so use is expected to decline for no other reason than the continued shift toward liquid detergents. Zeolites cost less than STPP, but are effective mainly on calcium ions. Often zeolites are used as a partial replacement of STPP for cost savings or as a substitute for STPP where phosphates are banned. However, they require another sequestering agent for magnesium ions. Zeolites also are included in formulations because of their ability to handle other ions, such as iron and copper, salts of which could redeposit on clothes and give undesirable results.

Use of citric acid and its salts (largely sodium) as a builder in detergent formulations is growing because of the shift toward liquids in which phosphates seldom are used. In powdered detergents, citrates are not used because of their low efficiency when compared with STPP and caking tendencies that cause problems in manufacturing. Bans on phosphates and the convenience of liquid detergents likely will push up demand for citrates in the detergent market. However, this market for citrates still will be small compared with food and beverage uses.

Most of the other chelating or sequestering products are in the large category of specialty cleaners. Their use in laundry detergents varies. But in most formulations, the concentrations are quite low, if they are used at all. Use in institutional and industrial cleaners probably accounts for the largest share of consumption.

Numerous other materials may be added to formulated detergents. These are added to perform such diverse actions as bleaching, foam regulation, solubilization, fabric softening and brightening, removal of proteinaceous stains, and prevention of redeposition of dirt. Not all of the possible materials will be in any one formulation, but most heavy-duty laundry detergents will have those needed to meet the perceived multifunctionality requirements of convenience in home use.

Bleaches also have been used to various degrees for a long time. Until the demand for convenience accelerated in the 1980s, chlorine bleaches (usually a solution of sodium hypochlorite) were added separately from the detergent. Those kinds of bleaches work well in cooler water. They can't be used in liquid-formulated products because they react with other components during standing. As a result of the deficiences in chlorine bleach, sodium perborate is the material of choice in multifunctional detergents. Sodium percarbonates and various organic peroxygens have been proposed as possible bleaching materials, but so far their commercial use is small.

Perborate bleaches are much less effective at low temperatures because of poor hydrolyzation. Higher concentrations of perborate can offset the low efficiency, but that also increases costs. To overcome that problem, a variety of bleach activators have been developed, designed to react preferentially with hydrogen peroxide from hydrolyzation of the perborate and form organic peroxy acids. The peroxy acids have higher oxidation potentials than hydrogen peroxide and provide reasonably effective low-temperature (typically below 60 °C) bleaching. In Western Europe, where most washing machines have heating elements and often washing temperatures are much higher than in the U.S. and Japan, the perborate bleaches work well without activators.

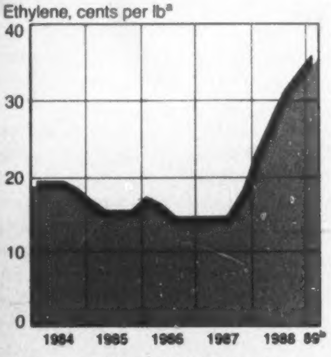
Addition of an activator and a perborate to make a detergent more multifunctional adds to the cost, and as yet it is uncertain whether consumers will pay a premium for this convenience and performance. The technology is present for perborates to be in powdered detergents, but the economics are in question, according to Linda J. Myrick, FMC's industry manager for peroxygen chemicals. As for liquids, a way to put a peroxide into a liquid detergent hasn't been found yet. FMC is actively pursuing a multifunctional molecule that will put peroxide into a bottle, Myrick adds.

A nonaqueous slurry containing liquid surfactants and a perborate might become commercial, speculates Rudi Moerch, vice president of new products and peroxygens for Degussa Corp. Moerch points out that perborates are stable in many organic systems. He also foresees dishwasher detergent formulations as slurries, but the peroxygen compounds probably will be peracids and not persalts.

Besides the basic components in a detergent formulation of surfactants, builders, and bleaches, many auxiliary materials are used to impart a special property to aid the total cleaning process. Enzymes, for example, have been in and out of detergents, particularly in Western Europe, for 25 years. In the U.S., the accelerating shift toward liquid heavy-duty and nonphosphate laundry detergents over the past decade has spurred use of enzymes in the protease and amylase families. Newer developments, such as alkaline cellulases for cotton fabric treatment and a genetically engineered lipase from Novo Laboratories in Danbury, Conn., stem from efforts to supply enzymes to meet demands in making multifunctional detergents. To make more new enzymes for such detergents, Novo expects genetic engineering technology to find wide use in this area, says Robert J. Petrowski, manager for market development. In a few years, Petrowski says Novo aims to produce all of its products through use of genetically engineered microorganisms, such as customized enzymes with better catalytic efficiency and formulation compatibility.

Even when well washed and bleached, most white clothing will retain a slightly yellowish color. To overcome this aesthetic problem, blue dyes began to be added to the rinse in laundering more than 100 years ago. Some of the dyes are still used, but most formulated detergents now contain optical brighteners or fluorescent whitening agents.

Rising prices hurt ethylene-based surfactants



a Typical price on U.S. Gulf Coast. b Estimated.
Sources: Pace Co., C&EN estimates

Chemically, these agents are complex derivatives of several classes of compounds. The most important are the stilbenes. The compound to be used in formulated laundry detergents depends on the kind of fiber to be cleaned and on washing conditions. The market for fluorescent whitening agents is growing as they become more widely used, and their concentrations in detergents, although small, increase, according to Joseph Huypen of Mobay Corp. Through its own development and purchase of other companies' product lines, Mobay offers fluorescent whitening agents that cover such requirements as light fastness, stability to chlorine, effectiveness with synthetic and wool fibers, and suitability for multifunctional detergents. Although no specific data are available, Huypen estimates U.S. demand for these agents last year at about 10 million lb.

In most laundry detergent formulations, surfactants and builders act sufficiently to remove soil from fibers and leave it in the wash liquor. Sometimes, however, the soil will be redeposited on clothes, giving a characteristic grey color that becomes deeper with repeated washings. To minimize possible soil redeposition, most formulators add materials that hinder approach of soil to fibers. For a long time, carboxymethylcellulose derivatives were used with success on cotton clothing. With the advent of synthetic fibers, various nonionic cellulose ethers have become widely used. As new antiredeposition agents with improved cost/performance properties are offered, consumption is forecast to increase.

Multifunctional detergents may include other auxiliary components to act as antistatic agents, solubilizers, and fragrances. Making multifunctional products with a dozen components to meet consumers' demands for performance, low cost, and convenience will continue to challenge detergent formulators. They will need whatever help that can come from the suppliers of detergent materials. □

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CHEMICAL & ENGINEERING

NEWS

Plastics Recycling

Industry responds to solid waste crisis
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NEWS

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JANUARY 30, 1989

News of the Week

- **Savannah River plant's nuclear reactors are still being plagued by mishaps, delaying plans to restart them later this year.** Page 4
- **AAAS's new executive director will be chemist Richard S. Nicholson, who is currently head of the mathematics and physical sciences directorate at NSF.** Page 5
- **The current in a new type of superconducting copper oxide prepared by Japanese researchers is carried by electrons, rather than electron vacancies, as in all previous copper oxides.** Page 5
- **Australian high school student, winner of science award for process to coat steel with diamond film, visits Penn State University during trip to U.S., part of his award prize.** Page 5
- **Chemical company earnings' strong growth pattern carried into last year's fourth quarter.** Page 6

Cover: Photo by C&EN's Ann M. Thayer

Letters 2

Concentrates
Business 17
Government 21
Science/Technology 23

The Departments
ACS Comment 29
ACS News 30
People 32
Newscripts 48

Business

ChemTek Partners, a recently formed venture capital firm aimed at emerging specialty chemical businesses, can provide help with R&D, marketing, production, and distribution, as well as funding. Page 19

Renewed interest in the fine chemicals business is being spurred by strong growth in several end-use markets. Page 20

Government

President Bush is urged to make hazardous waste cleanup under the Superfund program a top domestic priority. Page 22

Science

Level of science literacy among U.S. adults has not changed significantly in the 1980s, according to results of recent national survey. Page 24

Books

Risk communication as a new tool for environmental management is explored in new book by two Tufts University professors. Page 27

News Focus

With plastics currently constituting 30% by volume of municipal solid waste, industry is focusing waste reduction efforts on development of new technologies for plastics recycling. Page 7

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LETTERS

CHEMICAL SAFETY

Explosive pyridine derivative

SIR: Recently an explosion occurred in our laboratories during the attempted synthesis of 3-methyl-4-nitropyridine-1-oxide according to W. C. J. Ross [*J. Chem. Soc., C, Org.*, **1966**(20), 1816]. 3-Methyl-pyridine was converted into the corresponding 1-oxide using hydrogen peroxide and glacial acetic acid. After evaporation under reduced pressure, subsequent addition of sulfuric and nitric acid and slight heating as described, a sudden vigorous reaction occurred followed by an explosion after a few seconds.

Fortunately, thanks to the alertness of the experimenter and his colleagues, no personal injuries occurred. As the explosion is most probably caused by the presence of remaining peracetic acid from the nitrogen-oxidation step in the subsequent nitration step, we advise not to follow the published procedure for the synthesis of 3-methyl-4-nitropyridine-1-oxide.

A. v.d. Kuilen
J. A. J. den Hartog
Duphar B.V., Weesp, Holland

Alcohols in fuels

SIR: W. C. Lowrey's letter, entitled "Octane Enhancers" (C&EN, Dec. 5, 1988, page 3), included several statements that require a response. Lowrey implies that application of the federal blender tax credit to ethyl *tert*-butyl ether (ETBE) would be "unwise and unfair." Quite the contrary in the estimation of lawmakers who enacted the blender tax credit in 1980. Specific blend proportions of waivered fuels now in commerce were, in several cases, undetermined at that time. However, the use of alcohols in these fuels was clearly anticipated. The 1980 blender tax credit was simply a means of stimulating the future use of such fuel components. The application of the blender tax credit to ETBE is precisely the type of application anticipated by lawmakers in 1980. Recent letters to that effect have been sent to the Treasury Department by more than 70 members of the Senate. The applicability of the blender tax credit to ETBE is merely a clarification of current law, not enactment of new legislation.

Lowrey also invokes the very old and tired "food versus fuel" myth regarding corn used for ethanol. His citation of this fallacious argument indicates a lack of understanding about the international food and feed situation. As one example, less than 10% of the corn grown in the U.S. is used directly for human food. The majority is used for livestock feed, primarily as a protein source. Ethanol is derived only from the starch in corn. The protein is extracted and used in a variety of food and feed applications. The use of corn as a feedstock for ethanol has not [competed], and in the foreseeable future will not compete, with human requirements.

Todd C. Sneller
Administrator, Nebraska Gasohol Committee

Energy efficiency

SIR: In reference to a letter from Rep. Claudine Schneider (C&EN, Nov. 14, 1988, page 5), I would like to raise some questions concerning energy efficiency.

The so-called empirical results over the past 10 or more years of a 30% drop in energy required to produce a dollar of gross national product and a 40% drop in CO_2 emissions may be at least partially explained in the following. During the past 10 or 20 years, heavy industry (such as steel production) has been on the decline in the U.S. Such heavy industry tends to use more energy and produce more CO_2 than the more service-oriented economy we now have. Also, the lower value of the dollar now than 10 years ago would be expected to yield a lower energy per dollar figure.

The above-quoted figures for the U.S. as presented in the first paragraph of Schneider's letter were perhaps inadvertantly applied to the whole world in the second paragraph. Is this a correct application of these figures?

The important question therefore is: Have we really achieved this improved efficiency nationally or worldwide, or is this but another instance of conveniently interpreted or manipulated data? My opinion is that we have not achieved nearly so much as quoted in Schneider's letter. We need to do much more!

Joseph A. Counsil
Assistant Research Engineer
University of Missouri, Rolla

Fluoridation of water

SIR: In his defense of water fluoridation, Surgeon General C. Everett Koop (C&EN, Nov. 28, 1988, page 2) claims that "those who have had lifelong access to fluoridated drinking water experience less dental decay, on average, than those who have not had such access."

This is not true in Australia or New Zealand. For instance, primary schoolchildren in the Australian state of

Solid Waste Concerns Spur Plastic Recycling Efforts

With plastics taking up 30% of volume of municipal solid waste and costs of landfilling and incineration rising rapidly, waste reduction efforts focus on development of plastics recycling technology

Ann M. Thayer,
C&EN Northeast News Bureau

Baled plastic bottles from local communities await recycling

C&EN staff photo

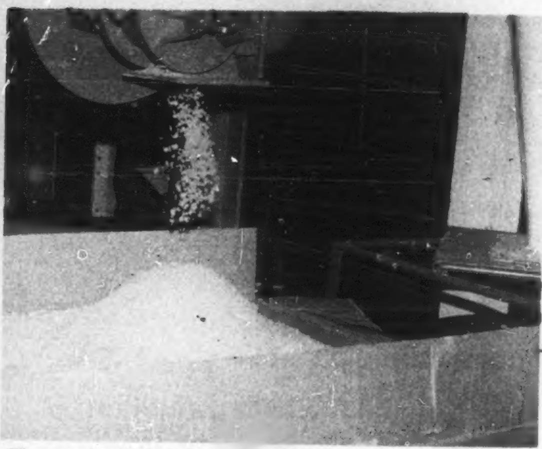
The management of solid waste is reaching a crisis in the U.S. and worldwide. This is illustrated by wandering garbage barges with no permission to land and by wastes washing up on beaches.

Every year the U.S. generates about 320 billion lb of what is called municipal solid waste, or postconsumer waste. About 85% of this trash is currently disposed of in landfills. Yet as the amount of solid waste increases—and the Environmental Protection Agency estimates that it will reach 380 billion lb by 2000—a third of the landfills are expected to close in the next five years. Many people are concerned that efforts to deal with the growing quantity of garbage are not moving fast enough.

Plastics make up only about 7% of solid wastes, according to figures prepared by Franklin Associates for EPA, but plastics and paper are the fastest-growing segments of such wastes. In 1987, the plastics industry produced a total of 55 billion lb of plastics, and the public discarded about 22 billion lb of that. By 2000, plastics production may reach 75 billion lb, and the public is expected to throw away about 38 billion lb of that, accounting for 10% of solid municipal wastes that year. Although not a significant proportion by weight, plastics have been targeted as a waste problem since, by volume, they are a very visible 30% of municipal solid waste.

Rapidly rising costs of landfilling, as high or higher than $100 per ton in some parts of the U.S., and of alternative waste treatment methods, such as incineration, are making it prohibitively expensive to deal with large amounts of waste. When coupled with the desire to conserve resources and have an environmentally acceptable means of reducing solid waste, recycling is often considered as an alternative. Recycling, although not inexpensive itself, can be less costly than other disposal methods because there is both a return on the reused materials and an offset of landfill charges. Of the more than 300 billion lb of solid waste produced, only about 10% is recycled annually. Aluminum and paper are the materials recycled most, with about 30% of the aluminum and 20% of the paper reprocessed. Only 1% of the plastics is recovered.

The apparent lack of movement in plastics recycling has helped to make plastics a scapegoat in the battle



C&EN staff photo

Clean, ground recycled polyethylene milk bottle chips fall from pilot plant equipment into bin

on solid waste. In the past decade, plastics have become increasingly prevalent because of their light weight, versatility in a range of applications, and convenience. But many plastic consumer items have short life spans and quickly make their way into the waste stream. More than half of the discarded plastics are found in the form of packaging, an area frequently targeted for recycling. Packaging, about one third by weight of consumer waste, consists primarily of paper (48%), glass (27%), and plastics (11%).

Much of the public believes that plastics cannot be recycled or safely incinerated and, because they do not decompose, that they should be removed entirely from the waste stream. One can argue as to whether plastics are in fact a major cause of the solid waste crisis, but the answer is almost irrelevant since plastics are generally perceived to be a significant problem.

The result has been the rapid introduction of a tremendous amount of local, state, and federal legislation that attempts to deal, one way or another, with the problems of solid waste. Much of the legislation has been aimed directly at plastics. On the federal level, former President Reagan signed the Plastic Pollution Control Act on Oct. 28, 1988, requiring that all six-pack ring carriers be made of biodegradable materials. The act will go into effect unless, in the next two years, EPA determines that it is either not feasible or that the by-products of the biodegradable materials are not environmentally safe. Efforts to deal with solid waste issues are also expected to continue with a reauthorization of the Resource Conservation & Recovery Act, which at this time promotes recycling only through government procurement guidelines.

The most comprehensive federal legislation proposed to date was reintroduced this month by Rep. George J. Hochbrueckner (D.-N.Y.). The bill, H.R. 500, entitled the "Recyclable Materials Science & Technology Development Act," has been described as the first measure introduced to authorize a comprehensive consumer product recycling program on a national level.

The bill stipulates that after a four-year joint review by EPA and the Commerce Department, all consumer items deemed recyclable would be identified and listed. Items determined to be recyclable must then be recycled, and all remaining items must be made biodegradable. After an additional year, the sale of certain nonrecyclable or nonbiodegradable consumer goods would be prohibited. The bill would establish an Office of Recycling Research & Information to distribute information and funds for research. Commerce would be directed to look into ensuring technology development, expanding the end-use markets for recycled materials, and encouraging the development of biodegradable products.

On the state level, the interplay of plastics and legislation began in 1978 with the introduction of the polyethylene terephthalate (PET) beverage bottle. In a relatively short time, nine states introduced "bottle bills," or deposit laws on the return of plastic bottles. In these states, the deposit laws account for collection of an estimated 80 to 95% of the PET bottles sold. At present, at least 30 states are looking into some sort of waste management legislation involving plastics.

The existing or proposed legislation runs the gamut of possible approaches, from the relatively benign sponsoring of feasibility studies for recycling to outright bans on the use of plastics. Other approaches include limited bans on certain items, such as polystyrene food containers, taxes on bottles or other containers, deposit laws, enforced usage of biodegradable materials, and restrictions on government procurement of recyclable or degradable items. In addition, voluntary or mandatory recycling programs are starting in many states. Susan Vadney of the Society of the Plastics Industry (SPI) Council on Solid Waste Solutions indicates that at least nine states have recycling programs and six more are likely to follow.

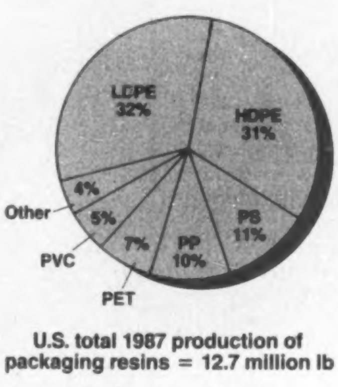
A few states such as Rhode Island, New Jersey, and California have become models for recycling programs, with Rhode Island and New Jersey having mandatory programs. In both states, several communities have had successful pilot programs for recycling that have included plastics. In October 1987, California enacted a mandatory beverage container redemption law (AB2020) with the condition that plastics manufacturers guarantee end-use markets for recycled plastics.

Massachusetts, in a joint study with Rhode Island, has recently released a Plastics Recycling Action Plan. The plan includes plastics as a significant part of a comprehensive recycling program aimed at reducing municipal waste levels 25%. The plan promotes pilot programs and further R&D into all aspects of recycling. Added incentives to recycling sometimes take the form of potential legislated penalties, such as taxes or deposits, that would be imposed if recycling goals, or those for certain materials, are not met. These incentives are often directed at bringing the recycling of plastics up to a level comparable to aluminum cans and glass bottles. Some states, like New Jersey, are also offering business loans, R&D funds, tax credits on equipment purchases, and market stimulation as incentives.

Five resins are in common use in consumer packaging

Thermoplastics, which account for 87% of plastics sold, are the most recyclable form of plastics because they can be remelted and reprocessed usually with only minor changes in their properties. Five resins are commonly used in consumer packaging applications.

Polyethylene is the most widely used resin. High-density polyethylene (HDPE) is used for rigid containers such as dairy and water jugs, household product containers, and motor oil bottles. Low-density polyethylene (LDPE) is often used in films and bags.



U.S. total 1987 production of packaging resins = 12.7 million lb

Source: Center for Plastics Recycling Research

Polyethylene terephthalate (PET) is used extensively in rigid containers, particularly beverage bottles for carbonated beverages.

Polystyrene (PS) is best known as a foam in the form of cups, trays, and food containers. In its rigid form it is used in cutlery.

Polyvinyl chloride (PVC) is a tough plastic often used in construction and plumbing. It is also used in some food, shampoo, oil, and household product containers.

Polypropylene (PP) is used in a variety of areas, from snack food packaging to battery cases to disposable diaper linings. It is frequently interchanged for polyethylene or polystyrene.

On a local level, some of the legislation already passed has made people take notice, since its approach has been more drastic. Suffolk County, New York, was one of the first counties to ban plastic food packaging—the apparent target being fast-food packages made of polystyrene. Similarly, Berkeley, Calif., banned all polystyrene packages made with chlorofluorocarbon (CFC) blowing agents. The Berkeley law requires that all fast-food restaurant containers be biodegradable by 1990.

Although the reaction by government has been fairly rapid and directed, the issue of plastics in the waste stream is complex. The number of legislative moves to ban plastics or replace them with biodegradable materials is increasing. Critics say that these approaches are based on misinformation and misconceptions, and are only a politically expedient response to the public's desire for solutions that appear to be environmentally safe. But biodegradable materials and plastics may not be the answer.

C&EN staff photos

Morrow (left): very ambitious objective. Pearson: ban on plastics is not the answer

"There are still a lot of unanswered questions about biodegradable plastics," says Mary Sheil, deputy director of New Jersey's Division of Solid Waste Management and one of the drafters of that state's mandatory recycling law. Among these questions are concerns about the degradation products and how they will affect the environment. In addition, the introduction of degradable materials is often considered at cross purposes to recycling, because the degradable items can become contaminants of the more stable recyclable materials. One of the most startling facts that is coming to light is that even materials that are expected to decompose, such as paper and foodstuffs, are not breaking down in landfills. Therefore, producing more biodegradable materials would not necessarily ease the burden on landfills.

Public perception and the resulting trends in legislation have led manufacturers of plastics and plastic products to realize that they either have to act and get involved with the issue or be prepared to shoulder much of the blame for the solid waste crisis and face tremendous restrictions on their industry. The companies' initial responses included the formation of both internal divisions and cooperative industry associations to approach the issues of plastics recycling and solid waste management.

"Fortunately, we had some visionary people," says Wayne E. Pearson, executive director of the Plastics Recycling Foundation (PRF), an independent, nonprofit organization started through the Society of the Plastics Industry in 1985 by 20 members of the plastics and allied industries. "This group recognized, before it was as apparent to most of us, that there was a solid waste crisis, that recycling was important and that [group members] needed to know more about it." The foundation now has 45 member companies, ranging from resin producers to container manufacturers to users of the containers, who are concerned about the attitudes driving today's legislation and would like to see it take a new direction. "The legislation is coming from a quick fix," says Pearson. "And it's too early to make simplifying decisions, unless you know the impact on society and the environment.

"But," he says, "what we can't let it do is cause us to panic. We are trying to get a message out there about recycling, but get it out there in a calm and rational way. We want to get to various legislators and let them know that when they have the facts, they will see that banning plastics is not the answer."

But how and where does a group like this get its facts? In 1985, PRF made its primary objective the establishment and support of the Center for Plastics Recycling Research (CPRR) at Rutgers University. Funds totaling nearly $2.3 million in 1988–89 to support research come from PRF, Rutgers University, and other organizations such as SPI, the National Science Foundation, the New Jersey Commission on Science & Technology (which has established CPRR as one of its Advanced Technology Centers), and several state governments and universities. In the near future, Rep. Jim Courter (R.-N.J.) is expected to reintroduce a proposal to fund the center as the National Center for Plastics Recycling, the hub of a national effort with other universities.

Starting up a research program in recycling is not an unlikely thing for plastics manufacturers to do, Pearson points out. "One of the things I don't think the public at all understands is that the plastics industry recycles every plastic, every thermoplastic, every day." He explains that the reprocessing of in-house scrap from the manufacture of plastic products has been a common practice for as long as the industry has existed. Thus, much of the technology for reusing plastics already exists. But, he notes, the use of in-house scrap is relatively straightforward, since collecting and sorting the materials is not necessary. So the question CPRR was given regarding plastics recycling was, Pearson says: "How do you gather it back from 240 million Americans and do something with it that makes any sense?"

Under a charter to advance R&D in all aspects of plastics recycling and reuse, the job has been given to Darrell R. Morrow, director of CPRR, and his staff. The center operates with three divisions—research, process development, and information services—that work on covering the scientific, technological, economic, environmental, and practical sides of recycling plastics. This includes defining and developing the necessary infrastructure to recycle plastics. This framework consists of four areas: collection, sorting, reclamation, and reuse. Unlike other materials such as paper, metal, and glass, which have been recycled for 40 years or more, the infrastructure for plastics recycling is not yet in place.

The center initially concentrated on reclamation and reuse and developed a technology for the reclamation of postconsumer waste plastics. After only two years, CPRR published nearly 25 reports based on its research and held conferences to provide for transferring the technology. "We want to disseminate the information as widely and in as timely a fashion as we can to help develop the infrastructure that will cause plastics to be included in the recycling stream," says Morrow.

C&EN staff photo

Dittman sits on plastic bench made at CPRR plant

In its first two years, CPRR also constructed and began operating what is potentially a commercial-scale pilot plant facility. "To be able to reduce the applied research to practice in a timely manner," says Morrow, "we realized that we had to have a process development and demonstration facility that was significantly larger than you would ordinarily expect to find at a university, or even in industry." He adds that this has allowed them to move along faster toward a commercially viable design.

Through this focused effort, CPRR has produced a technology transfer manual that describes in detail the setup and operation of a plastics recycling plant. The hope of CPRR is that making the technology available will foster the commercialization of plastics recycling. There are currently 14 licensees of the CPRR process worldwide; two of them are looking into building plants in the near future.

The process developed at CPRR is said to be similar in its layout to those used in private industry. Most plastic reclamation systems are designed to work with rigid containers, such as PET beverage bottles, and HDPE milk or household product containers, because they are currently the easiest postconsumer items to collect and sort. PET beverage bottles are actually not one, but several materials: a PET body (clear or green), a pigmented high-density polyethylene (HDPE) base cup, aluminum cap, label, and adhesives. To separate these components, either a dry or wet separation method based on one or more of the different physical properties of the materials can be used.

Frank W. Dittman, project manager at the CPRR plant, describes its operation after the containers have been collected and delivered to the plant. The bottles are sorted by hand to separate out the more valuable resins. "We are looking at mechanical sorting based on optical and electrical principles," says Dittman, "but whether that's going to beat hand sorting at cost, I don't know. You can sort by hand pretty quickly." After sorting, the bottles are shredded and ground into chips for processing. The chips are then air classified, which, Dittman says, means that the lighter weight paper and other contaminants are separated in an air cyclone from the heavier plastic chips.

To remove the labels still attached to the chips, a cost-effective and efficient means of removing a waterproof adhesive had to be devised. After finally finding a detergent wash that would work, he explains, it had to be optimized with respect to temperature, washing time, concentration of detergent, power of mixing, and, of course, concentration of chips.

In the case of the multicomponent PET beverage bottles, once the labels are removed, the lighter HDPE fraction is separated from the heavier PET and aluminum pieces in a hydrocyclone system. It is at this stage that other reclamation methods often differ, using a separation step based on flotation methods; Dittman suggests that the hydrocyclone system will be an improvement over the flotation methods. The HDPE chips are then dried and collected.

The PET and aluminum chips require further drying so that they can be electrostatically separated. This is the most expensive part of the entire process. "The aluminum cap is only 1% by weight of the bottle," explains Dittman, "but the equipment to remove it represents about 30% of the investment in the plant. It's out of balance, and we are trying to remove the aluminum more cheaply." The process—which at the CPRR plant can handle about 600 lb per hour, or a potential capacity of about 5 million lb per year—generates clean, well-separated (99.9%) granulated plastic chips that can be sold to a manufacturer who uses the resins.

The chips sell for about 25 to 35 cents per lb for PET (with less than 100 ppm of aluminum), and 17 to 25 cents per lb for HDPE. In comparison, virgin PET costs about 50 to 60 cents per lb, and HDPE resins about 40 cents per lb. The center combines these and other factors in evaluating the financial aspects of operating a plant. "In our engineering manual we analyzed the economics and showed that a profitable plant should be able to process 20 million lb a year or more," says Dittman. He notes that the investment for a plant of that size would be about $2.5 million and it would pay for itself in three to five years.

Other available reclamation technologies for rigid HDPE plastics are made by Transplastek of Canada and A.K.W. of West Germany and are similar in design to the CPRR process with granulating, washing, and separation steps. Transplastek uses a proprietary flotation tank method to separate plastics by density, whereas the A.K.W. method is based on the hydrocycloning technology.

Much of the resin reclamation and reprocessing technology comes from overseas, as the Europeans and Japanese have been involved in recycling for a longer period of time. There are other reclamation processes for different resins, which have been developed by or licensed to private companies, but because these are usually proprietary the details of their operations are not known.

Morrow makes a point of calling the system designed at CPRR a "resin recovery system," to stress the fact that it will work on about five different resins. Currently PET and HDPE can be processed together and are easily separated because of their different densities. The center hopes to add polystyrene and polyvinyl chloride to the mixed plastics stream they process. But, with the present technology, PET and PVC cannot be run together since they have similar densities.

"We have a very ambitious objective," says Morrow. "What we have challenged ourselves to is to make our resin recovery system a universal reclamation facility." Ideally, he explains, one would like to be able to feed in mixed, even granulated, plastics and have pure, generic resins come out the other end. This would remove the need for hand sorting and, for example, the separate processing of pigmented and unpigmented HDPE containers. Morrow notes that economics are driving this stage of the reclamation process: Colored HDPE is less valuable than uncolored HDPE, which has greater flexibility in end uses.

The value of recycled materials is present only if there are available markets, and plastics have become the second most valuable recyclable material after aluminum. The greatest return on recycled plastics is gained when the resins are reused in their original or similar applications, or by producing materials with added value, such as engineering plastics. If the properties of the resins are not compromised by the reclamation process, and if free enough of contaminants, generic resins can be sold to the manufacturers of

C&EN staff photo

Plastic lumber made from recycled resins is removed from ET/1 extruder at CPRR pilot plant

Chemical recycling of plastics is alternative to mechanical methods

In addition to mechanical methods of reusing plastics, such as molding or extruding, polyester resins also can be reclaimed through chemical means and used to produce new polymer compositions. Eastman Chemicals (a division of Eastman Kodak) and Freeman Chemical Corp. have led in developing the chemical recycling of polyester resins. By one of three reaction paths, polyethylene terephthalate (PET) can be used to produce polyols (for polyurethane foams) and unsaturated resins, or it can be broken down into its original starting components and repolymerized. Eastman Chemicals, through the Plastic Bottle Institute of the Society of the Plastics Industry, has provided detailed discussions of these reactions.

PET consists of repeating ethylene glycol and terephthalic acid (TPA) units joined together by ester linkages. Aromatic polyols, hydroxyl-terminated short-chain molecules consisting of TPA and glycol units, can be produced from PET in a one-step glycolysis reaction. The idea behind the reaction is very simple: High-molecular-weight PET is broken down into short-chain pieces through a catalytic reaction of PET and diethylene glycol. By heating a mixture of PET and diethylene glycol in the presence of a manganese catalyst, the polymer chain is cut into short fragments, and the ethylene glycol portions undergo exchange with the free diethylene glycol. This reaction is allowed to proceed until an equilibrium between the two glycols is reached and the PET has been reduced to short-chain polyols.

The aromatic polyols resulting from the reaction can be mixed with commercial polyols, blowing agents, surfactants, catalysts, and polymeric isocyanates to produce a rigid polyurethane foam. When compared with control foams produced from commercially available polyester polyols, the foams produced from reclaimed materials were found to have essentially the same properties.

Freeman Chemical uses about 25 million lb of postconsumer PET bottles and film scrap to make polyols for the production of rigid foams. The company estimates that more than 50% of the laminate foam insulation used for construction is made from recycled material.

PET resins also can be reused to produce new unsaturated polyester resins. This takes a two-step reaction. The first reaction is similar to that used to make the polyols but, instead of ethylene glycol, propylene glycol is used in the glycol exchange. The end products of this reaction include bis(hydroxyethyl)-terephthalate and bis(hydroxypropyl)terephthalate diesters, mixed ethylene glycol and propylene glycol terephthalate diesters, and free ethylene glycol and

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plastic products as a replacement for virgin material. But Food & Drug Administration restrictions prohibit use of recycled resins in food applications, making one major plastics market inaccessible to recycled resins.

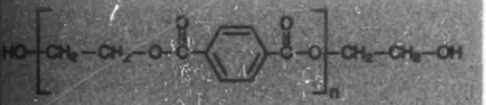
Mixed, or commingled, plastics must be dealt with differently to find end uses. Several technologies exist for mixed plastics, such as the ET/1 extrusion process from Advanced Recycling Technology of Belgium and a compression-molding process from Recycloplast of West Germany. At CPRR, another pilot plant with an ET/1 extruder has been installed to make plastic lumber out of mixed plastics. Lower-melting plastics in the mixture act as a matrix that carries other plastics, and even up to 40% contaminants, such as paper, metal, glass, and dirt, into the mold. The resulting product can be treated and used like wood in nonconstruction applications such as decks, picnic tables, and park benches. Reclaimed HDPE resins are also used to make flower pots, pipe, bottle base cups, pails, and drums.

A few companies make mixed plastic items commercially. About six years ago, Eaglebrook Plastics of Chicago started recycling HDPE plant scrap, developing its own technology for cleaning and reclaiming the resin to be sold back to manufacturers. Eaglebrook since has extended its technology to deal with postconsumer waste and now buys bales of bottles from community collection centers. An offshoot company, Eaglebrook Profiles, was recently opened to make plastic lumber profiles using a proprietary, continuous-extrusion process developed in-house.

Similarly, Polymer Products, a division of Plastic Recycling Inc. of Iowa, is a young company that has started buying industrial scrap and postconsumer plastics, generally commingled, to make car stops, speed bumps, traffic bollards, and plastic lumber. Floyd Hammer, chairman of Plastics Recycling Inc., says that when he started the company he had in mind to manufacture value-added products with their own end-use markets, rather than deal in the more volatile commodity resins. He noted that two years ago there wasn't a market for mixed plastics products, but that the company has been building its market slowly, but successfully, as one of the few small companies making these types of products.

In contrast, PET end-use markets have been developing for at least 10 years. When the PET bottle was introduced in 1978 and was collected in states with deposit laws, the industry for recycling them and reusing them began to develop. PET resins can be reused to make polyols for insulation and unsaturated resins for bathtubs, shower stalls, boat hulls, and auto panels. Reclaimed PET is also used for strapping, paint brushes, geotextiles, fibers for fiberfill and carpets, and other textile applications.

Wellman Inc. of Clark, N.J., the largest consumer of reclaimed PET, recycles PET beverage bottles and scrap to manufacture fibers, fiberfill, geotextiles, and other products. Dennis Sabourin, vice president of Wellman, indicates that the company used about two thirds of the PET bottles collected in the U.S., or about 100 million lb, in 1988. About 150 million lb of PET bottles were collected nationwide and recycled in 1988, or about 20% of those manufactured. This is a substantial increase over the 8 million lb collected in 1979 at a time when the return of plastic bottles was just begin-



Polyethylene terephthalate (PET)

propylene glycol. Since all of the products are hydroxyl-terminated, reacting them with a dibasic acid like maleic anhydride produces new unsaturated polyester condensates.

This synthetic method has been successfully tested on PET from beverage bottles (a 2-L bottle, for instance, consists of about 50 to 60 g of PET). Producing unsaturated resins from reclaimed PET takes about half the time as other methods and produces materials of equal molecular weight, acid value, and viscosity. Glass fiber-reinforced laminates and unreinforced castings prepared from the reclaimed PET material test favorably with other materials.

Although Eastman Chemicals does not currently use the unsaturated resin synthesis from reclaimed PET in its production, it does frequently use a methanolysis reaction, which breaks down PET into its original starting materials, to reprocess large amounts (tens of millions of pounds) of Kodak film scrap. As David Cornell, manager of technology and manufacturing in Eastman Chemicals' polyester recycling business unit, says, "It makes good sense for us at Eastman Kodak to recycle our scrap as it helps treat the solid waste problem and saves on our disposal cost."

The methanolysis begins with reasonably clean PET scrap to which a catalyst and methanol are added. This mixture is heated under pressure to force the PET to depolymerize. The end products are ethylene glycol and dimethyl terephthalate (DMT). Pure DMT and ethylene glycol are obtained through recrystallization and distillation, respectively. These pure materials can be used as feedstocks for the synthesis of new polyesters.

A few special considerations must be dealt with when reusing PET from consumer sources in chemical recycling. For example, the PET must be clean and free of contaminating materials. Using plant scrap assures the manufacturers of both the identity of the resin and its purity. Using mixed colored resins may pose a problem, although when they are used in products that are not visible to the consumer, such as foam insulation, color is not a factor.

Whether an economic advantage is realized when using reclaimed materials depends on several factors, ranging from the relative costs of obtaining and reprocessing the materials to the cost of virgin materials or feedstocks. In addition, the supply of materials and the scale of the reprocessing effort may play a significant role.

ning. CPRR estimates a potential market now for at least 500 million lb of reclaimed PET, increasing to more than 900 million lb in 1993. Similarly, 55 million lb of HDPE containers were recycled in 1988 and the potential market is estimated at 440 million lb, growing to 660 million lb in 1993. By most estimates the market for plastics reuse is growing.

According to an analysis of markets and economics of recycling by R. M. Kossoff and Associates of New York City, although the market for plastic resins can fluctuate widely, economic incentives are present in all aspects of the recycling chain. The firm sees the business as highly segmented, with opportunities at a variety of levels. These include collection, reclamation, selling of reclaimed resins, end-use products, and equipment manufacture. But as Richard M. Kossoff, director of the study, says, "In the long run, the markets will have to lead."

Increasing costs of virgin resins and viable end-use markets are currently making the recycling business attractive, and more and more companies, both large and small, are entering the business. The 1988 Plastic Bottle Recycling Directory and Reference Guide published by the Plastic Bottle Institute of SPI currently lists 67 companies that buy bulk bottles for recycling, 47 companies that sell reprocessed plastics, 50 companies that purchase reprocessed plastic, and 54 companies that manufacture equipment for recyclers.

Most people in the plastics recycling business will tell you they can always use more plastic than is currently available, but that the bottleneck is in getting the materials collected from consumers. Sabourin indicates that Wellman could use more than twice the amount currently available and as much as three and a half times that in the next two years. That more than 200 million lb of plastic containers were recycled with no organized recycling program, other than deposit laws in nine states, suggests that the level of plastics recycling and the requisite end-use markets will probably rise with increased collection efforts.

Having produced a working reclamation plant, CPRR is shifting its R&D emphasis to the areas of collecting and sorting plastics. The center is in the process of publishing another manual to help communities and industry establish the infrastructure for collecting and sorting plastics as a part of a comprehensive recycling program. In following the progress and analyzing the results of several community pilot programs, the center has found that the success of these programs depends on many factors. The most important factor is the careful design and planning of a program to fit a given community.

Even though including plastics in recycling programs is a new concept, participation rates can be as high as 70 to 90%. "If you want to get serious about collecting, you make it very simple for the consumer to participate," says Pearson. This usually means curbside pickup programs for trash and recyclable materials in suburban communities. In comparison, drop-off programs only have a 10 to 30% participation rate. Although mandatory recycling laws do help to directly communicate the need for recycling and enforce it, Pearson feels that with sufficient education about the solid waste problem and the value of recycling, most people are very willing to participate. And the value of education is not to be underestimated, because the most difficult initial obstacles to overcome are the previous misconceptions people hold about plastics not being recyclable.

The extent to which a community gets involved in recycling depends on the economics of collection, transportation, handling, reprocessing, the revenues from sales of recycled materials, and the offset of landfill or incineration fees. The large number of variables makes the overall economics of recycling programs complicated. Based on current costs and market prices, the CPRR economic model predicts that an average suburban community with landfill charges of $45 per ton or more cannot afford not to recycle. Although this should encourage some communities to become involved in recycling, this does not mean that local governments must become entrepreneurs in the plastics end-use market. However, government subsidies to start programs and stimulate market growth might be necessary.

CPRR suggests that communities work toward developing regional Material Recovery Facilities (MRF) to handle all the recyclable materials collected. Several MRF facilities exist across the U.S., and the number being looked at is growing rapidly. These larger facilities, serving several communities, can handle sorting and densification (baling or shredding) in addition to sale and transport of recyclables to reprocessors.

Promoting recycling and collecting plastic containers has led to the development of other organizations. One of these is NAPCOR, the National Association for Plastic Container Recovery, a nonprofit association of 12 major PET resin and container manufacturers. "We work with communities in recycling efforts to either encourage including PET in existing programs or to have it included in programs under development," says Luke B. Schmidt, president of NAPCOR. NAPCOR has a goal of achieving a 50% recycling rate for PET bottles by 1992.

Geotextile fabric for sanitary landfill liners is made by Wellman Inc. from recycled green PET bottles

NAPCOR works on a project-by-project basis to encourage collection, Schmidt says. These projects are usually in demonstration programs. Currently, they are working in at least seven states giving financial support, technical assistance, and public education and promotion programs. In addition, the member companies of NAPCOR have pledged to use a voluntary coding system developed by SPI to identify resins. The code consists of a number and letter symbol that can be imprinted on containers in the molding process and should help in the sorting of resins.

The Plastic Bottle Institute of SPI and the Council on Plastics & Packaging in the Environment (COPPE) work to educate and provide information on plastics recycling and waste issues. The Plastic Bottle Institute, with 23 industrial members, publishes newsletters in addition to its extensive plastics recycling directory. Along with other organizations, it hopes to inform the public about the recyclability of plastics and the existence of viable end-use markets. COPPE works to communicate information to industry, the public, and government about plastics recycling and waste management.

"We want to educate the public as to what can and should be done so that decisions can be made on an informed and not an emotional basis," says Connie Pitt, communications coordinator for COPPE. Although not a lobbying organization, it does interact on matters of public policy as an information source and in a peer review capacity. There are 42 companies in COPPE that cover a broad base in the plastics industry. Noel H. Malone, manager of marketing in Eastman Chemicals' polyester recycling division, says that the large number of groups spanning the plastics industry is beneficial. "The industry is deep and wide, and specific groups can focus in on specific problems," he says.

New Jersey Division of Solid Waste Management deputy director Sheil is encouraged that the plastics industry appears to be joining together and moving forward on recycling. "Unlike other industries [glass and paper], the plastics industry is a very diverse group, . . . especially by the time you get to the end product," she says. "If the states hadn't put the pressure on, it wouldn't have happened." Although the industry has come a long way toward recycling plastics, comments Sheil, recycling plastics hasn't yet become real on a large scale, and it will remain to be seen what happens in the next few years.

In addition to getting involved in recycling through organizations such as PRF, NAPCOR, and COPPE, the plastics industry is expanding its own internal efforts. Many of the major resin manufacturers, such as Du Pont, Dow Chemical, Mobil Chemical, and Eastman Chemicals, have taken positions on and responsibility for solid waste issues and established corporate divisions to focus on plastics recycling and/or solid waste management. These divisions look into the governmental, environmental, and business aspects.

Of course, companies see the support and promotion of plastics recycling as vital to their positions in the marketplace and the growth of their companies. As happened with the aluminum can, the promotion

Speed bump is one of a number of end use products made by Polymer Products from commingled plastics

of a product as recyclable lets the public perceive it in a positive light and helps to maintain a market. And joint ventures, acquisitions, and the building of recycling businesses offer the plastics industry new markets and promotional opportunities.

Mobil Chemical is a producer of polyethylene and polystyrene resins and a major manufacturer of polystyrene products. In addition to recycling all in-house scrap, the company purchases 100 million lb of polyethylene film scrap to use in the production of institutional trash bags. Robert J. Barrett, general manager of Mobil's Solid Waste Management Solutions unit, expects that business opportunities will continue to arise from the solutions to solid waste problems. An example is Mobil's $4 million joint venture company, Plastics Again, with Genpak of Glens Falls, N.Y.

Genpak, a plastic products manufacturer, and Mobil are in the process of opening and operating one of the first plants to recycle polystyrene foam items such as food containers, cups, and cutlery. The materials are being collected from Massachusetts schools and institutions by New England CRInc, a major reclamation firm and recycled materials end-use manufacturer. The plant has a capacity to recycle 3 million lb per year of polystyrene resin, which will be reused by the companies or sold to producers of insulation, fence posts, and flower pots. The new company is expecting a profit by 1992.

Similarly, Dow has entered into a joint venture agreement with Domtar of Canada to operate what the companies hope will be by 1990 a self-sustaining PET and HDPE recycling business. The North American company is expected to take postconsumer plastics and, using a proprietary Dow process, convert them into resins for use in Domtar's manufacturing or to be sold by Dow.

Other industry efforts to "close the loop" of product manufacture, recycling, and resin reuse include Procter & Gamble's marketing of a plastic household product container made from recycled PET. Johnson Controls, a major manufacturer of PET beverage bottles and containers, is also involved in promoting recycling efforts. Internally, the company recycles inhouse scrap and is working on proprietary R&D efforts in recycling. As a container manufacturer, Johnson Controls is also taking an interest in the design of packaging to make it more recyclable. A company spokesman indicates that approaches are being worked on to begin marketing nonfood containers from recycled materials. Manufacturers looking to use recycled resins are concerned with getting consistent quantities and quality of the materials to make these efforts economically feasible.

Although plastics have been targeted in the battle on solid waste, and both government and industry have responded, plastics are only one part of the growing solid waste problem. The importance of investigating alternatives in waste disposal is becoming obvious to all involved. And new organizations, such as the Council on Solid Waste Solutions of the SPI, are growing out of the plastics and other industries. Unlike PRF, which emphasizes plastics recycling, the Council looks into all aspects of the solid waste problem, focusing on reaching local, state, and federal governments to influence legislation and on evaluating waste treatment technologies.

Alternative solid waste treatment methods are being explored and plastics recycling will probably continue to be among them, because it doesn't seem likely that our society will entirely give up their plastic products. Morrow makes the important point that plastics should be integrated slowly into the recycling scheme, starting with beverage bottles and moving on to other types of packaging, to provide time for the collection, reclamation, and end-use infrastructure to grow. Forcing too much, too soon, into the existing structure could do more harm than good in terms of a collapse of the effort and backlash from the apparent failure to recycle plastics. The outlook on biodegradable plastics, as generally expressed by the plastics industry, is that they may only find limited applications in agriculture or in dealing with litter.

EPA's Office of Solid Waste has proposed that an integrated system of waste reduction, recycling, incineration, and landfilling be established. This view seems to be supported by most industries and many legislative and environmental groups, but with different emphasis on the different components. EPA has also set a goal for recycling 25% of solid waste nationwide.

Although the details and issues of solid waste management are both complex and controversial, it appears that after reducing the amount of waste through recycling and burning that which can be safely incinerated in waste-to-energy conversion facilities, the levels of materials left for landfills can be greatly reduced. Still left to be dealt with are the issues of safe and cost-effective incineration, air and ash toxicity levels and disposal, establishment of a nationwide recycling infrastructure, and development of efficient and environmentally safe landfilling methods. ☐

ChemTek, like other venture capital operations, will look for a fairly aggressive return on its investments, Harvey says. The partnership will need a fairly high return—between 40 and 60%—to justify the high level of risk it will be undertaking in the certain knowledge that "not all our ventures will succeed." That is why, Harvey says, the partnership will seek minority investments in a portfolio of startup operations. "We know that some investments might not be productive and we may lose some or all of our investment."

ChemTek will be looking at specialty chemical ventures referred to it by other venture capitalists or referred via Battelle, Harvey says. "We'll also go to American Chemical Society meetings and visit areas of the country where there are large pockets of chemistry expertise," he adds.

Most of all, Harvey says, "we're looking for entrepreneurs with experience who will devote their full time to the venture." Although the technology is important, he says that the quality of a venture's management does make a difference in its success or failure. "Give me a grade 'B' technology and grade 'A' management anytime" over a spectacular new technology with unproven managers in charge, he adds.

Huthwaite says that the partners will be looking for specialty chemical ventures using a broad definition of specialty chemicals. As far as the partnership is concerned, anything that is not a commodity chemical business will be considered a specialty. Huthwaite says that the partners have 10 to 12 areas of particular interest. However, he is reluctant to discuss them for fear that in naming them he might inadvertently turn away someone with a venture the partnership might ultimately like.

Both Harvey and Huthwaite have practical business experience running startup business operations. Harvey, for instance, has headed up an electro-optics venture Du Pont had with Battelle. Huthwaite worked for a venture capital subsidiary of specialty chemical concern EchoLab in St. Paul, Minn.

Marc Reisch

Good growth forecast for fine chemicals

Fine chemicals have long been the stepchild of the chemical industry. Placed somewhere between commodity chemicals and the high-value-added specialty chemicals, these compounds, important though they are as intermediates to a number of industries, have gained little respect.

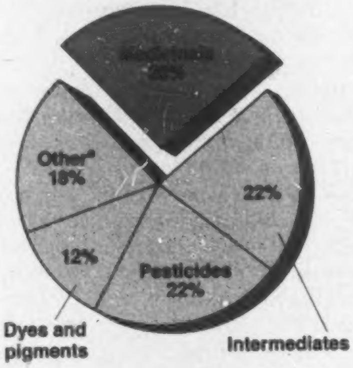
However, the situation may be changing as growth occurs in end-use markets for fine chemicals, according to a new study by Kline & Co., the Fairfield, N.J.-based market research group.

According to the study, the $15 billion fine chemicals business represents only about 8% of the $185 billion U.S. industrial chemicals market. But good growth potential and profitability are making this little-understood segment more attractive.

Fine chemicals are defined as high-value substances sold in low volumes. They go primarily to the pharmaceutical, agrochemical, dyes and pigments, and photographic industries. Kline cites examples of fine chemicals, including the analgesic acetaminophen, high-purity acids used in the production of semiconductors, and many of the intermediates used to make drugs and pesticides.

Fine chemicals, unlike performance chemicals which are usually formulated mixtures, are pure substances. They garner high prices because of their purity and complex processing.

Medicinals are largest share of fine chemicals market



Total 1987 consumption = $15 billion

a Includes aroma, photographic, and food chemicals.
Source: Kline & Co.

The surge in interest in fine chemicals is being sparked by the rapid growth of generic drugs and agrochemicals in which fine chemicals are used as active ingredients and intermediates and by the level of activity in the merchant market. This is creating new challenges and opportunities for fine chemical suppliers.

According to Kline, the growth in generics is occurring as pharmaceutical and pesticide companies are becoming more willing to purchase intermediates on the merchant market. This willingness to buy from merchant suppliers comes because of cost pressures and stringent government regulations, including waste treatment and disposal and compliance with Occupational Safety & Health Administration regulations.

The Kline study projects a real dollar growth rate of 3.4% per year over the next five years for fine chemicals. Segments showing better-than-average growth include bulk medicinals, aroma chemicals, essential oils, food-grade chemicals, electronic chemicals, and various types of intermediates. Kline expects growth in the merchant segment of the market to outpace the market as a whole.

The structure of the fine chemicals industry can be classed into three types of companies, according to Kline. Captive producers, such as Monsanto, BASF, and Ciba-Geigy, produce fine chemicals primarily for their own pharmaceuticals, dyes and pigments, pesticides, and photographic products. They also sell to a lesser extent on the merchant market. Independent suppliers, like ChemDesign of Fitchburg, Mass., and White Chemical of Newark, N.J., have fine chemicals as their chief business and sell primarily on the merchant market. A third group includes integrated business units of major chemical companies such as PPG Industries and Occidental Chemical.

William Storck

Past Decade Shows No Gain In U.S. Science Literacy

New studies that also allow comparison of science literacy in U.S. and U.K. show "dismally" low levels in both countries

James Krieger, C&EN Washington

There has been no significant change in the level of science literacy among American adults in the 1980s, according to evidence from a recent national survey of public knowledge in the U.S. about science and technology.

Moreover, another new survey of science literacy carried out in the U.K. broadens the scope: "In two of the world's oldest and most prominent democracies, at least nine out of 10 citizens lack the scientific literacy to understand and participate in the formulation of public policy on a very important segment of their national political agendas," says political science professor Jon D. Miller, director of the Public Opinion Laboratory at Northern Illinois University, which undertook the U.S. survey.

More specifically, results of the U.S. study indicate that only about 6% of American adults are scientifically literate, that no progress has been made in this regard over the past decade, and that a meaningful solution involves longer-term changes in the educational system. "The British results," Miller says, "suggest that we are not alone in our problems, and I think that it is most likely a problem faced by virtually all industrialized nations."

To what extent that is the case may become better known in the near future. The U.S. and U.K. survey results were presented at a symposium on cross-national measurements of public understanding of science and technology, held during the annual meeting of the American Association for the Advancement of Science earlier this month in San Francisco. Presiding at the symposium, Jean Gabolde, director for scientific and technical policy of the Commission of the European Communities, Brussels, noted that surveys of European countries are planned.

Gabolde stressed the need to be able to compare the European Community's 12 member countries, which are not in the same state of scientific development. Come 1990, he says, studies of the public perception of science and technology will exist for the U.S., U.K., Japan, Europe, and European countries. The European studies, he says, will use the same approach as that taken in the U.S. and the U.K.

Meanwhile, the U.S. survey and that in the U.K. are bringing refinements to the study of science literacy. The U.S. effort, for instance, builds on two previous surveys carried out by Miller and his colleagues at the Public Opinion Laboratory and forms a bridge to them.

Miller points out in relation to the concept of literacy in general that the level of skill or ability in reading and writing should be viewed as a continuum, ranging from virtually no skills to the most sophisticated writing ability. In contrast to a continuous distribution, however, literacy is a threshold measure.

And it is a relative measure, Miller notes. The level of skills needed for a person to be considered literate changes over time. Also any definition of literacy is inherently relative to the character of the society in which it is used—the same definition of functional literacy, for example, not being appropriate for

New survey of U.S. science literacy provides bridge with past measures . . .

	Trend measure with 1979 and 1985 variables[a]	New measure with 1988 variables[b]
Estimate of science literacy	5.6%	5.6%
Understanding of scientific process of thinking	12.1	12.1
Understanding of scientific terms and concepts	34.0	28.1
Understanding of the impact of science and technology	53.0	49.9

. . . and permits a comparison of science literacy in U.S. and U.K.

	U.S.	U.K.
Estimate of science literacy	5.6%	7.1%
Understanding of scientific process or thinking	12.1	10.4
Understanding of scientific terms and concepts	28.1	28.5
Understanding of the impact of science and technology	49.9	57.6

Note: Number of responses = 2041 (U.S.) and 2009 (U.K.). a Calculation using same variables employed in 1979 and 1985, but using 1988 data. b Calculation using new variables and 1988 data.

Quiz items form basis for Anglo-American comparative index of science knowledge

	Percent correct	
	U.S.	U.K.
The center of the Earth is very hot	80.3%	86.3%
The oxygen we breath comes from plants	80.6	59.9
Radioactive milk can be made safe by boiling it	64.1	65.1
Lasers work by focusing sound waves	36.0	41.6
Sunlight can cause skin cancer	96.9	93.5
Hot air rises	97.0	96.7
Electrons are smaller than atoms	42.7	30.9
The continents are moving slowly about on the surface of the Earth	80.1	71.7
Antibiotics kill viruses as well as bacteria	25.5	28.6
The earliest humans lived at the same time as the dinosaurs	36.8	46.2
Which travels faster, light or sound?	76.1	74.7
Is all radioactivity man-made or does some occur naturally?	65.3	74.3
Does the Earth go round the sun, or does the sun go round the Earth?	72.5	82.8
How long does it take for the Earth to go round the sun?	44.9	34.1
Doctors tell a couple that their genetic make-up means that they've got a one in four chance of having a child with an inherited illness. Does this mean that: • If they have only three children, one will have the illness? • If their first child has the illness, the next three will not? • Each of the couple's children has the same risk of suffering from the illness? • If their first three children are healthy, the fourth will have the illness?	71.1	82.1

both advanced industrial societies and Third World agricultural societies. Further, the selection of a threshold level for the definition of literacy is not an exact science, but rather a judgment.

For science literacy, Miller and his associates have tried to develop measures that would indicate what a citizen needs to know to be reasonably effective and to function in society. Knowing Earth goes around the sun, he explains, isn't considered to be optimal about what one ought to know about the universe. Rather, it is an attempt to establish a floor to see how many people fall above and below that floor.

And science literacy is not unrelated to general literacy. The problems associated with basic literacy in U.S. society, Miller says, are serious and are relevant to concerns about a broader public understanding of science and technology. "For those millions of Americans who are not functionally literate," he says, "the world of science is as distant as Pluto."

Miller directed previous national surveys of U.S. science literacy in 1979 and again in 1985 (C&EN, June 23, 1986, page 37). They made him aware, he says, of a need for improved measures of science literacy. With National Science Foundation support, he was able to design and collect the most recent survey in the summer of 1988. A similar study was being conducted at the same time in the U.K. by John Durant, deputy director of the department of external studies at the University of Oxford, and his colleague Geoffrey Evans.

Durant and Evans collaborated with Miller to establish a domain of overlap between the two questionnaires being used, so that a comparison could be made of public understanding of science in Britain and the U.S. Durant says that this collaboration is the first he is aware of in which two independent surveys have been expressly designed for this purpose. Durant presented the first preliminary results of the U.K. survey and of work on the data sets involving the two.

The Northern Illinois surveys have been based on what Miller thinks of as the three dimensions of science literacy: an understanding of the process or methods of science for testing models of reality, a basic vocabulary of scientific and technical terms and concepts, and an understanding of the impact of science and technology on society. The 1988 survey continued that framework, but revisions aimed at improving it involved changes in the items used to measure two of the three dimensions.

An open-ended question about the meaning of scientific study forms the core of the measure of public understanding of the process of science. As a check against this open-ended question, all the studies have included a set of items about astrology, one of which asks whether astrology is very scientific, moderately scientific, or not at all scientific. To be classified as having a minimally acceptable level of understanding of the process of science, a respondent had to be able to provide a satisfactory open-ended explanation of what it means to study something scientifically and to recognize astrology as not at all scientific. By this measure, 12% of American adults displayed a minimally acceptable level of understanding, compared with 9% in 1979 and in 1985.

On the science literacy dimension of vocabulary, or scientific constructs, Miller argues that if an individual cannot comprehend basic terms like atom, molecule, cell, gene, gravity, or radiation, then it would be nearly impossible for that person to follow much of the public discussion of scientific results or public policy issues pertaining to science and technology.

To measure such comprehension, the 1979 and 1985 surveys included a series of two-part knowledge items that first asked each respondent to rate his or her own comprehension of a term. If the respondent reported a clear understanding or a general sense about a term, he or she was asked to explain what the word or phrase meant in an open-ended response. If the respondent indicated little understanding, he or she wasn't asked for further explanation. The approach made the data collection more acceptable to adult respondents.

The scientific knowledge measure in the 1979 and 1985 studies was based on self-reported items for radiation, DNA, and GNP [gross national product]. These same items were repeated in 1988 to allow for a comparison. (34% of American adults in both 1988 and 1985 reported at least one clear understanding and one general sense on these three items, thus meeting a minimal criterion for scientific vocabulary.)

The 1988 U.S. and U.K. studies included an expanded number of scientific and technical knowledge items, some in a true-false quiz format and others posed as freestanding questions. Each study included 15 to 20 scientific and technical knowledge items, 10 of them identical in the two studies. In the U.S. study, respondents could score from zero to 10. For constructing an index of scientific literacy, those with a score of seven or more on this measure were classified as having an adequate level of understanding. In the 1988 study, about 28% of American adults met this criterion.

The third dimension of science literacy concerns an understanding of the impact of science and technology on society broadly and on the daily lives of individuals as consumers, parents, and citizens. As implemented in the three studies, this dimension went beyond such scientific understandings as the size of an electron or the time location of humans and dinosaurs. The idea is that for what might be thought of more broadly as technological literacy, some knowledge about computers or antibiotics or radioactivity might aid a person in coping with some of the technologies or public policy issues that he or she may confront currently.

The 1988 study involved construction of a six-item index to measure this technological literacy dimension. For example, respondents received one point each for providing a "false" response to several statements, such as antibiotics kill viruses as well as bacteria. One point each was also given on several other items—for example, indicating that all the children of a couple with a one-in-four chance of transmitting a genetic condition would have the same probability of having that condition. Respondents with a score of three or more out of six were classified as having an adequate understanding of the impact of science, or an adequate level of technological literacy. Some 50% of adult Americans met this criterion in 1988.

Miller admits to not being satisfied with the measurement of this dimension. But he says that given the items collected in previous studies and in 1988, it is the best estimate available, and the 1988 measure is an improvement over the previous measures.

Combining the three separate indexes leads to the finding that approximately 6% of American adults can be classified as scientifically literate in 1988. This compares with levels of 7% in 1979 and 5% in 1985.

As a check on the changes in two of the dimensions, the research group calculated the 1988 estimate of scientific literacy twice. One calculation, Miller explains, used the same variables employed in 1979 and 1985, but used 1988 data. The other calculation used the new variables and the 1988 data. In both cases, the overall scientific literacy estimate came out to be 5.6%—indicating, Miller says, that the new measures are an appropriate bridge to previous measures.

The new study also explored more broadly the distribution of scientific literacy. Five variables were studied. Age was investigated, with respondents separated into three groups: 18 to 29, 30 to 50, and 51 and over. In terms of education, respondents were also separated into three groups: less than high school graduation, high school graduates, and baccalaureates. Gender was explored. Separation was also made according to respondents having had no college-level science courses (biology, chemistry, or physics) versus those having had some courses. And included was a measure reflecting whether the respondent's employer is engaged in scientific or engineering work.

Miller says that if a single variable had to be chosen to predict science literacy, that single one is having taken one or more college-level science courses, even for people who did not finish college or who were two-year college students. Obtaining a baccalaureate adds marginally to the likelihood of being scientifically literate, he says, but it is clear that it is the science course experience rather than the general degree experience that makes a difference. By inference, he adds, this result suggests that the high school science experience has little impact on subsequent scientific literacy.

All of the measures used to construct the estimate of scientific literacy for the U.S. were collected in the U.K. at about the same time. Oxford's Durant explains that the U.K. quiz consisted of more than 20 straightforwardly factual questions on a wide range of sciences, including mathematics, physics, geology, chemistry, and biology. Together, these items constitute what the research group has termed the Oxford Scientific Knowledge Scale. It was used along with a smaller battery of items on the processes and norms of scientific inquiry to provide the analysis of British public understanding of science. From the Oxford Scientific Knowledge Scale, 14 items overlapped with the U.S. study to form the basis for a comparison.

The results, Durant says, don't justify much cause for complacency in either country. He notes, for example, that on an extremely elementary factual science quiz, "the American public performed only slightly less dismally than the British." He notes that on one item, under half of Americans and under a third of Britons know that an electron is smaller than an atom. And another item shows that about the same proportions in each country know that Earth goes round the sun once a year.

"Now, for most of the public not to have caught up with Sir J. J. Thompson, Robert Millikan, Niels Bohr, and all the rest may perhaps be excused on the grounds of the relatively esoteric nature of atomic physics," Durant says. "But what reason shall we give for the fact that most of the public has not yet caught up with Nicolaus Copernicus and Galileo Galilei?" ◻

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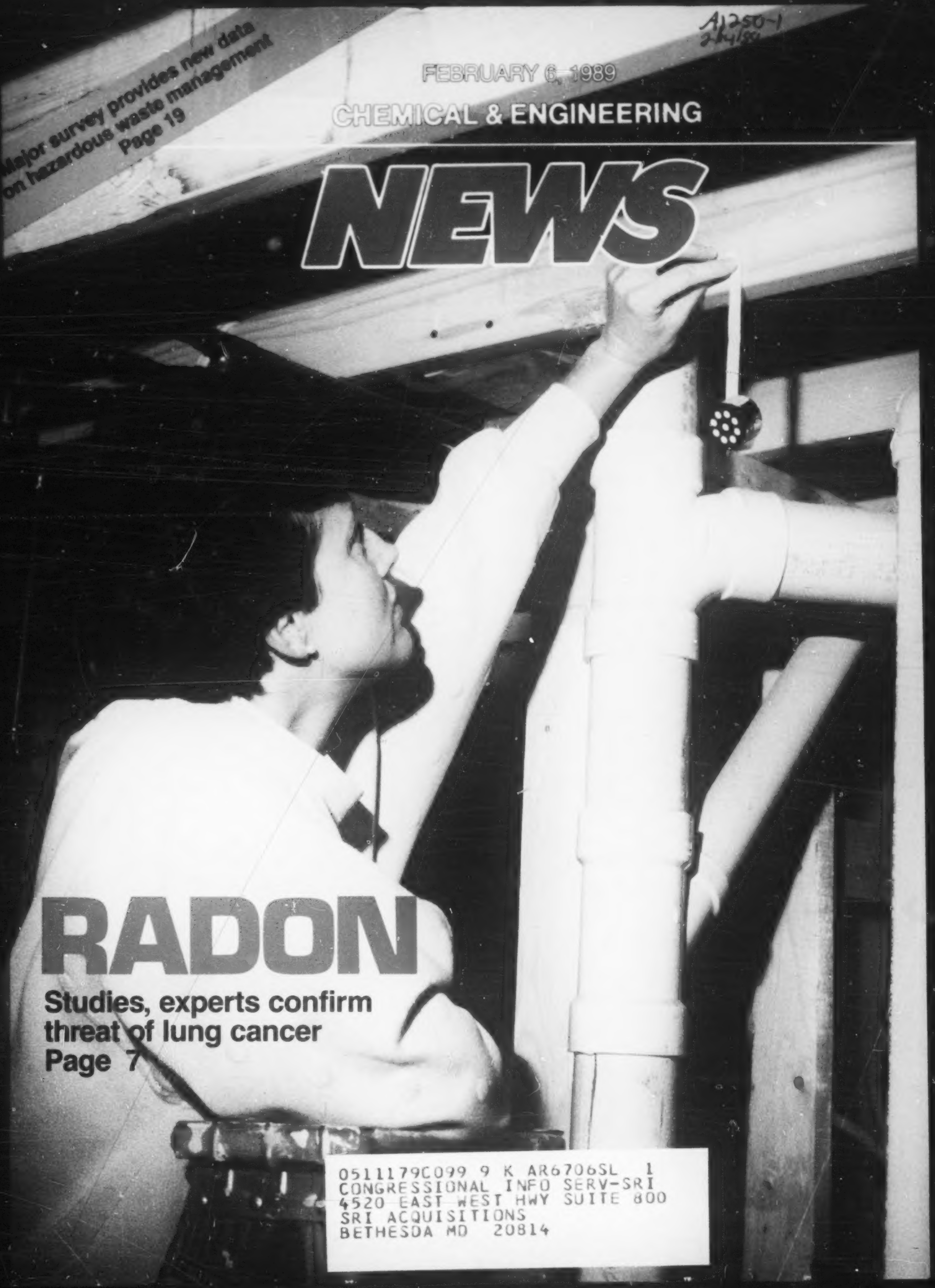
CHEMICAL & ENGINEERING

NEWS



Major survey provides new data on hazardous waste management
Page 19

RADON

Studies, experts confirm threat of lung cancer
Page 7

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CHEMICAL & ENGINEERING NEWS

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News of the Week

- **The West German Chemical Industry Association has suspended Imhausen Chemie, which is charged with supplying Libya with plant and technology for producing chemical weapons.** Page 4
- **Bush Administration's environmental policies get off to a fumbling start.** Page 5
- **U.S. 13-year-olds place last in mathematics and close to last in science in international assessment of achievement in those fields.** Page 5
- **Negative impact of leveraged buyouts on R&D confirmed by NSF data.** Page 6
- **Emissions of chlorofluorocarbon refrigerant CFC-12 to be reduced via recycling, and a new blend of compounds may offer a substitute for it.** Page 6

Cover: Photo by C&EN's David J. Hanson

Letters 2

Concentrates

Business 14

Government 18

Science/Technology 23

The Departments

Awards 31

Newscripts 48

Business

Current high prices for major-volume aromatics such as benzene, toluene, and xylenes may ease, as supply begins to catch up with strong demand. **Page 16**

Government

Survey on treatment, storage, disposal, and recycling of hazardous waste is basis for development of EPA database. **Page 19**

Establishment of an International Chemical Warfare Authority is proposed to help stem the spread of chemical weapons. **Page 21**

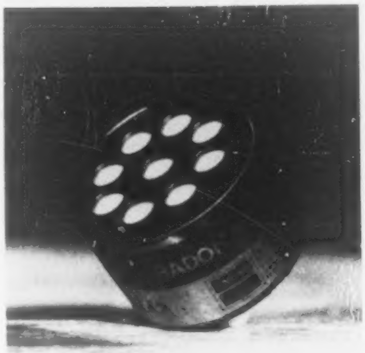
Science

Prominent chemists review frontiers in chemistry in symposium at AAAS annual meeting held last month in San Francisco. **Page 24**

A scanning tunneling microscope has been used to obtain images of the internal structure of an isolated molecule. **Page 27**

Genetic evidence accumulates that all humans today trace back to one woman who lived about 200,000 years ago. **Page 28**

Total synthesis of powerful immunosuppressant agent, FK-506, is achieved by Merck chemists. **Page 29**



News Focus

Most studies and scientists agree that radon poses a cancer risk, but debate continues over the action level set by EPA for the indoor air pollutant. **Page 7**

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LETTERS

Gasoline additive

SIR: In his long letter (C&EN, Dec. 5, 1988, page 3) William J. Wells III presents strong technical arguments supporting the use of ethyl *tert*-butyl ether (ETBE) as a gasoline additive in lieu of or in addition to methyl *tert*-butyl ether (MTBE). He skirts the real issues, however: costs and federal tax support of the grain ethanol business, which exists only because of the special tax subsidy granted to production from facilities employing this inefficient and uneconomical route to ethanol.

Without this crutch, alcohol from grain is not competitive with petrochemical source ethanol. Further, despite its stated technical advantages, ETBE has not been able to gain a foothold in the market, even when it is made from much cheaper petrochemical ethanol. Congress should not extend this unfair gift to the grain farmers and alcohol producers by extending it to ETBE produced from grain.

E. H. Ivey
Houston

Nuclear waste

SIR: In his letter (C&EN, Nov. 7, 1988, page 66), Jack Jacox, from the nuclear field of technical consultation and public relations, misinforms and misleads readers with his statement, "There is no long-lived radioactive waste! The long-lived isotopes are fuel that should be reprocessed. . . .Other rational developed nations are reprocessing their spent fuel." First, among the aforesaid isotopes are some that are not used as fuel, such as cesium-135 and iodine-129 with half-lives ranging up to millions of years. Second, although reprocessing can recover most of the original fissile elements for reuse, about 2% of the plutonium and other long-lived radionuclides inexorably accumulates as a residue that must be permanently stored in isolation from the environment. [MIT faculty, "The Nuclear Almanac," Addison-Wesley Publishing Co., Reading, Mass., page 260 (1984).] Third, the only commercial U.S. reprocessing plant, in West Valley, N.Y., was closed down in 1972 because contamination of the plant, site, and workers became unmanageable, including leakage of plutonium into the Springville dam three miles away. According to the Department of Energy's Willis Bixby, currently in charge of the cleanup, $391 million has been spent so far, and he estimates the total cost at $1 billion (the same as for Three Mile Island). A federal court recently ordered DOE to clean up similar contamination at the government reprocessing plant in Fernald, Ohio, which DOE estimates will also cost $1 billion, part of its estimate of $175 billion to clean up 17 federal nuclear sites. (Santa Barbara *News Press*, Dec. 3, 1988).

Fourth, Jacox's loose categorization of all long-lived isotopes as fuel includes plutonium, which along with uranium can serve as fuel in fast-breeder reactors, where additional plutonium is also created from the uranium. But practical fast breeders are currently pie-in-the-sky. They are being "abandoned as a costly dead end" [Worldwatch Institute, "State of the World 1987," W. W. Norton & Co., New York, page 79 (1987)], related to such risks as the spontaneously inflammable liquid sodium used for heat transfer, and the tons of plutonium in a single reactor load invading the environment by leakage, meltdown, and hydrogen explosion. The half-life of plutonium is 24,400 years, and its toxicity is such that 1 lb finely divided in fallout and inhaled as dust from an atom bomb explosion or a hydrogen explosion of a reactor as at Chernobyl [Hawkes N., et al., "Chernobyl: the End of the Nuclear Dream," Random House, New York, page 98 (1986)] contains about 10 million lung-cancer doses for nonsmokers and 2 billion doses for smokers [Gofman, J. W., "Radiation and Human Health," Sierra Club Books, San Francisco, page 488 (1981)]. A Lawrence Livermore study in 1986 found that Chernobyl emitted as much long-term radioactive nuclides on the planet's surface as all previous explosions of nuclear bombs and tests. The small hydrogen explosion at Three Mile Island fortunately did not breach the building [Eisenbud, M., "Environmental Activity," 3rd ed., Academic Press, New York, page 369 (1987)].

The only commercial breeder built in the U.S., the now defunct Fermi 1, suffered a partial meltdown in 1966, and a classified report stated that a maximum radioactive release at this plant could lead to 66,500 deaths ["Possible Effects from a 300 MW Nuclear Reactor Located at Laguna Beach, Michigan," Atomic Energy Commission (1957)]. In a "major policy decision," Britain in 1997 will shut down Dounreay, "probably the only operating fast reactor fuel reprocessing plant anywhere," and in 1994 will shut down its neighboring prototype fast-breeder reactor. Fast-breeder R&D spending "will be pared to about $17 million annually, less than a fifth of

Radon Tagged as Cancer Hazard By Most Studies, Researchers

Although some scientists argue that EPA's action level of the radioactive gas in homes is too low, it seems clear that moderate or high concentrations of radon pose major lung cancer risk

David J. Hanson, C&EN Washington

In three short years, the radioactive gas radon has progressed from relative obscurity to a cause of high anxiety as an indoor air pollutant. Behind this anxiety are highly publicized health risk projections indicating that the likelihood of dying from lung cancer increases if radon is present in the home (radon is a decay product of uranium, which occurs naturally in soil in many parts of the U.S.). Public reaction to this health risk has ranged from fright to little concern, and many people have raised questions about the way the issue has been handled by the government. But one thing seems clear: Although a number of questions remain about the risk at low levels of exposure, most researchers agree that moderate or high levels of radon are a health problem.

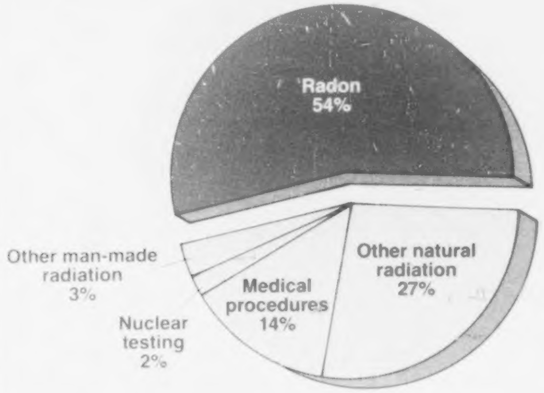
The Environmental Protection Agency has taken the lead in making the public aware of the radon risk, although other federal agencies and many researchers are contributing information on the subject. In 1985 EPA evaluated the existing data on the lung cancer risk from radon exposure, and recommended that residents consider taking some kind of remedial action if the radon level in their houses exceeds 4 picocuries (pCi) of radon per liter of air. But EPA's analysis isn't the only one available, and there is a large volume of data, human and animal, to consider when making a decision about radon.

That radon might cause health problems has been known for a long time. Reports of a "miners' disease" suffered by underground miners in central Europe as far back as the late 1500s are now assumed to be cancer. But not until the 1930s was it recognized that radon played a role in the miners' lung cancer problem.

The first detailed studies of radon effects on miners were done in the 1950s in the U.S., when the Atomic Energy Commission began looking into the problem at its Grand Junction, Colo., operation. An occupational health standard was actually set in 1955 at 10 pCi per L of radon in air by the International Commission on Radiological Protection and at 100 pCi per L by AEC. It also was discovered that the high incidence of lung cancers in underground miners probably was caused by radiation from radon, rather than by the gas itself.

However, it wasn't until about 1970 that radon's potential risk to a wider population became known. At that time the Public Health Service (PHS) and the predecessors to the Department of Energy began looking into the discovery that homes built on reclaimed land over uranium mill tailing deposits were building up high levels of indoor radon. Later, a similar increase in radon levels was found in houses built on other reclaimed land from mining operations, particularly phosphate mines in Florida. At the time, radon contamination in houses was believed to be mostly associated with industrial mining and mill-

Radon makes up most of normal background radioactivity



C&EN staff photo

Guimond: four key elements to strategy for tackling radon

ing. Although there were some early indications that the problem was more pervasive, nothing was done.

The watershed event occurred in 1984. In December of that year the home of Stanley Watras was discovered to contain stupendous amounts of radon. Watras was an engineer working on the Limerick nuclear power plant in eastern Pennsylvania. He found that he was setting off the plant's nuclear monitors upon entering the plant in the morning. When the source of the radioactivity was traced, it was Watras' home, which measured a whopping 2700 pCi per L in the basement, a far higher amount than most miners were ever exposed to. The media attention generated by this discovery led to the present public awareness of radon.

Richard J. Guimond, director of EPA's Office of Radiation Programs, has been studying the problem of radon for nearly 20 years. He says after the Watras case, EPA Administrator Lee M. Thomas asked him to put together a strategy for investigating radon levels in Pennsylvania and for determining how significant the radon problem was nationally.

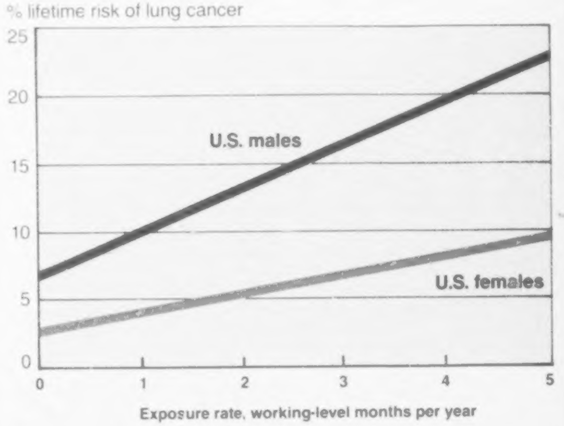
"That strategy, which is basically the one we are still following, has four key elements," Guimond says. "First was problem assessment. Basically, it is to sort out how many houses are affected and what are the levels of radon in them. Second is mitigation and prevention. We didn't want to be in a position of telling people they had a radon problem and a health risk if we didn't have good ways for them to fix it. Third was developing a testing program for companies that wanted to test homes for radon so they would meet some minimum standard. Last was public education. We felt we needed to give the public as good an understanding as we could of the magnitude of the problem, what it means to them as individuals, and how they can sort out whether they have a radon problem or not."

The data used to determine whether people have a health risk or not come primarily from studies done on underground miners in the U.S. and other countries, especially Canada, Sweden, and Czechoslovakia. In every instance, the studies showed an excess in deaths from lung cancer when miners were exposed to high levels of radon and its decay products, called radon daughters or progeny. By using what is known about the radon exposures of these men and extrapolating these data down to the expected lifetime risk an individual might have from radon levels in the home, researchers have come up with the lung cancer estimates put forward by EPA and others.

EPA has made what may be the highest estimates of lung cancer deaths caused by radon. In its citizen's guide EPA says that from 5000 to 20,000 deaths annually may be attributed to radon and radon progeny. The Committee on Biological Effects of Ionizing Radiation of the National Academy of Sciences did a major study of radon and other alpha-emitters a year ago, and its analysis of the health risk from radon put maximum lung cancer deaths at about 13,000 per year. In 1984, the National Council on Radiation Protection & Measurements (NCRP), a nonprofit corporation chartered by Congress to, in part, develop and disseminate information on radiation, published an analysis of the health effects of radon and radon daughter exposure. That report puts total lung cancer deaths from radon at about 9000 annually.

In addition to the gross observations that more underground miners get lung cancer and the statistical analysis that defines just how much more at risk miners are, there also have been animal studies demonstrating that radon causes lung cancer. For years Fred T. Cross, a senior staff scientist at Battelle Pacific Northwest Laboratory in Richland, Wash., has been looking at how radon causes cancer in animals. "We see effects exclusively limited to the lungs," Cross says. "These studies have been going on since the late 1960s, so we have collected quite a bit of data on the effects of indoor radon. In our experiments, we have exposed animals to mixtures of radon and radon daugh-

Risk of cancer from radon progeny at low exposure levels



Source: National Academy of Sciences report "Health Risks of Radon and Other Internally Deposited Alpha Emitters"

Radon decay products are where the health threat lies

Radon is a naturally occurring element formed from the radioactive decay of radium-226. There are three radon isotopes, radon-219 and radon-220, which have half-lives measured in seconds and consequently decay before they ever go anywhere, and radon-222. The last isotope has a half-life of 3.82 days and decays by alpha particle emission through a series of solid, short-lived radioisotopes that are collectively called radon daughters or progeny. Two of the daughters in the chain are polonium-218 and polonium-214, which are also alpha emitters. Polonium-218 has a half-life of 3.11 minutes and polonium-214 has a half-life of just 0.0002 second.

Radon itself is a noble gas, and is, therefore, extremely unreactive. That is why, once formed, radon-222 is free to bubble up out of the ground or dissolve in water without getting trapped anywhere along the way. If radon is inhaled, it is usually immediately exhaled. Because of this, then, it is the two alpha-emitting polonium isotopes that are of greatest health concern. Because they are solids, they can become trapped in airways where their radioactivity can damage nearby cells.

Origins of radon vary, but soil is the largest source

Millions of curies	Annual radon emissions
Soil releases	2400
Groundwater (potential)	500
Oceans	34
Phosphate residues	3
Uranium mill tailings	2
Coal residues	0.02
Natural gas emissions	0.01
Coal combustion	0.0009
Human exhalations	0.00001

Source: National Council on Radiation Protection & Measurements

ters, uranium ore dust, cigarette smoke, and various combinations. By going through these mixtures and then excluding everything but radon daughters, we have found that radon daughters by themselves can produce lung cancer in lab animals."

Cross says that all of the animal studies result in lung cancer risk coefficients in animals, especially rats, that are very, very similar to the coefficients resulting from the underground miner studies. "The data support the linear, no-threshold theory" of cancer formation, he says. Cross points out that the studies show that radon exposure produces cancer no matter how low the levels of exposure, including down to common indoor radon concentrations.

These lowest exposure levels produce effects because the delivery system for the radiation to the lungs is very effective, according to Naomi H. Harley, research professor in the department of environmental medicine at New York University Medical Center and author of much of the 1984 NCRP report on radon. "It's really the short-lived radon daughters that deliver the dose," she says. "Radon itself is radioactive, but the dose really does not come from the gas because of its geometry. Radon as a gas gets in the whole airway where it will be breathed in and out, but the daughters are solids and a fraction of these can deposit on the airways' surfaces as you breathe. It is really an efficient system for irradiating the cells which are crucial to formation of lung cancer," Harley emphasizes. "The range of the alpha particle is very short, about the thickness of a piece of paper, less than 70 μm. The epithelium where the stem cells are located is only 40-μm thick. So these stem cells, which generate cancer, are right in the target range."

Although the obvious lung cancer risk is to certain undergound miners, the discovery of high levels of radon and radon progeny in peoples' homes has added a heightened dimension to the problem. The Watras home in Pennsylvania that had such very high radon levels sits on a geologic formation called the Reading Prong, a uranium-rich outcropping of granite that runs northeast from about Reading, Pa., through northern New Jersey and into New York. More than half the homes in the area that have been tested show high levels of radon. For a while, it was hoped that only unusual areas like the Reading Prong would have high readings. But soon, EPA was finding radon all over the country.

EPA has established a radon concentration of 4 pCi per L of air as an "action level" for homes and buildings. According to the agency's risk projection, if a person is exposed to this level of radon and radon progeny for a lifetime (70 years) there is a 1 to 5% chance that that person will die of lung cancer. The choice of 4 pCi per L has received criticism from many areas. EPA does not consider this a safe level of radon concentration, but it is lower than that proposed by some other organizations. The 1984 NCRP study, for instance, says that 8 pCi per L of air is an acceptable level for homes. One reason for the 4 pCi-per-L level is that it is the concentration EPA recommended for homes that were built on contaminated sites from uranium mill tailings or reclaimed phosphate mining areas. These had been thought to be special cases, and perhaps the risk was set higher than it would have been for the general population. To change the radon level on homes now and recommend a lower one would be unacceptable to those living on the contaminated sites.

EPA also uses this 4 pCi-per-L concentration because it is a level that can be achieved with practical remedial work to a home with higher concentrations. "We took a look at how achievable reducing radon concentrations was, and it was pretty easy to get houses down to 4 pCi per L," Guimond says. "We had not done much research at that time on naturally occurring radon in houses; most of our data were on houses we had dealt with in Colorado and Florida. So the concentration we set was, to a great degree, based on information as to what was then technologically achievable." He adds that when the decision was made, it

Variety of kits to detect radon levels in the home are offered by a number of companies

Many brands of detection kits are available to determine radon concentrations in the home. The kits are usually of two types, short term and long term, the major difference being the reliability of results.

The short-term tests usually rely on activated charcoal to collect the radon daughters over a period of two to four days, after which the container is sent to a company that measures the radioactivity by counting gamma rays from radon daughters lead-214 and bismuth-214. Then, taking the length of exposure into account, these data are back-calculated to determine radon concentration.

The long-term test is called a track etch monitor and uses a piece of special polymer film on which an alpha particle can make a "track." After leaving the sample for a minimum of three months, but for up to a year, the film is etched with sodium hydroxide, which makes the tracks big enough to count electronically. Based on the length of exposure, the radon concentration can then be calculated.

If done very well, under controlled conditions, both types of detectors give reasonably accurate measurements of radon levels. The major problem with the short-term test is that radon concentrations in the home can vary considerably, from day to day or week to week. One sample taken in winter may be much higher than a similar sample taken in summer. Or a measurement made during a dry spell can be higher than one during a rainy period.

The Environmental Protection Agency suggests that several short-term tests be made to get an accurate value. But a single test is useful to see if radon concentrations are really excessive.

Long-term tests, although generally giving good average values, are not as accurate at very low levels of radon.

EPA has instituted a program to test radon detection devices to make sure they meet a minimum standard. These radon measurement proficiency programs send samples of known radiation levels to companies requesting to be certified, and the analyses are checked to see if the companies obtain values within 25% of the true value. The director of EPA's Office of Radiation Programs, Richard J. Guimond, says that this much variability has no effect on whether a home has high radon levels.

"We set up the program so people would still make the right decision even if the measurement company was off by plus or minus 50%, or even 70%," Guimond says. "We set the recommended measurement scheme up to be conservative. By setting up the sample in the basement with the doors and windows closed, we generally believe the reading will be a factor of two to four higher than you would get over an extended period of time averaged over all levels of the house. So, for example, if somebody gets a reading of 6 pCi per L, and the measurement company is off by 25%, then the value is between 4.5 to 7.5 pCi per L." But if the value is really only half that much, or around 3 pCi per L, extended measurements in the house would determine that. "So the conservatism is built in," Guimond says.

One public interest group, Buyers Up, a spinoff of Ralph Nader's Public Citizen organization, tested some companies for radon test accuracy and concluded that most did poorly. It was a quick and dirty test in which seven companies were each sent eight samples, and the results were not encouraging. Public Citizen says three of the companies "failed" the test, with errors ranging from 28 to 67% higher than the approximately 20 pCi-per-L samples used. As a result, the citizen's group called for greater regulation and more stringent controls on these companies from EPA.

The seven companies in that one test are just a tiny fraction of the companies formed to do radon measurements. Larry Siegelman, publisher of Radon Press Inc., in Alexandria, Va., has been trying to keep track of the industry's growth. "As of last December," he says, "we estimated there were between 2500 and 3000 companies doing radon tests, and, if everyone follows up on EPA's recommendation that they get their houses tested, we project about $4 billion in

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could not be shown feasible to lower average home levels to 1 or 2 pCi per L of air.

With the concept that homes should have radon concentration no higher than 4 pCi per L firmly in mind, the agency had to decide what it could do. At the time, in the early 1980s, there was a severe paucity of funds for the radiation programs. Budget deficits were straining EPA's resources. And, Guimond says, Congress was a little leery about a widescale program. "There was uncertainty about what the federal role should be in cases like this," Guimond explains. "Some lawmakers were reluctant because of the question of should the government get involved with people in their individual homes. And, if the problem was as big as we thought, there might be a hue and cry for a federal bailout, something akin to a Superfund for each homeowner."

The publicity surrounding the high levels in homes on the Reading Prong in 1985 forced the government to move. With what funds it had, EPA began measuring radon levels in homes and working on radon mitigation techniques. Other researchers, some of whom had been studying radon and its effects for a long time, also got involved. The Energy Department, Department of Housing & Urban Development, Farmers Home Administration, Veterans Administration, and National Park Service all have initiated programs principally aimed at determining radon levels in homes in various areas of the country.

Most studies are finding radon everywhere. EPA's studies have been the most extensive to date, mainly because Congress gave the agency the mandate and the funds to do a pair of studies of radon concentrations when it reauthorized the Superfund law in 1986. The study currently under way is a state-by-state short-term look at radon level in counties. The tests are all short term and measurements are taken in the lowest levels of the home, usually the basement. To date,

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C&EN staff photos

Home radon detectors come in two types: long-term track etch (above) or short-term charcoal canister (right)

revenues over the next three or four years." If the growth continues as it has over the past year, Siegelman says, the number of companies in the business could increase 300% in the next year.

EPA says that it investigated only about 1500 testing companies in the latest round of its certification program. Of these, 700 were primary companies—that is, they do their own manufacturing and analysis—and the rest secondary companies. In response to the criticisms of this program, and at the suggestion of its science advisory board, EPA is making some adjustments to this program. Among its adjustments will be more blind testing of measurement companies, requiring only the primary manufacturers to be tested, and making sure the secondary firms meet administrative requirements.

If detection tests reveal a high level of radon in the home, EPA recommends doing some sort of mitigation. The agency has published a handbook on this as well, called "Radon Reduction Methods." Reduction methods range from such simple techniques as natural ventilation—opening windows—to block-wall ventilations, which EPA estimates could cost up to $5000. According to Naomi T. Harley, research professor in the department of environmental medicine at New York University Medical Center, who is doing detailed research on how radon gets into homes and how to eliminate it, the method that is effective most often is subslab ventilation. In this technique, pipes are inserted through the concrete basement slab, and radon beneath the house is drawn up through the pipe by a fan and vented away from the house. EPA says the method can cut radon concentrations 90% or more.

Harley, based on her experience, would like to see national legislation regarding radon in houses. She thinks new homes should be required to be built on a good, porous base of crushed rock or its equivalent, so all gas underneath the house could be vented easily. If all homes were built this way, no new houses would have radon problems. Older homes would have to be measured for radon when bought or sold, eventually identifying and correcting the problems in these houses.

Radon also gets into the home in water, especially if groundwater is the source. According to Guimond, however, this is a very small risk compared with the radon that comes into the home from the ground. "But people are very concerned about their water in the U.S.," Guimond says. "Maybe one third of the population does something about its drinking water—buys bottled water, uses filters, or something." He emphasizes that even though water concentrations of radon can be very high, even thousands of picocuries per liter of water, it is not ingestion of radon that is a health problem, but radon in the air. "As a rough rule of thumb, we divide the concentration of radon in water by 10,000 to estimate how much gets into the air. So a concentration of 1000 pCi per L in water would only add about 0.1 pCi per L to the air. It is a concern we have that people will be more worried about their water than their air," Guimond says.

EPA has announced results for homes in 17 states. By the end of this year, it will have results for eight more states. "The state survey," Guimond says, "is to help each state set its own priorities as to what to do." A national survey also has begun. "We placed in 5000 homes randomly selected across the country, detectors on a slightly different basis," he says. "The detectors will be in place for a whole year at every level in the house. In addition, we will be getting information on lifestyle, how much time is spent in the basement, and how the house is constructed." Data will take about a year and a half to collect.

When EPA announced its latest results from the state survey in September last year, it made the pronouncement that has created the biggest activity around radon so far. EPA Administrator Thomas, with the support of Vernon J. Houk, assistant surgeon general for PHS, proposed that every home in the U.S. be tested for radon. This recommendation was made because EPA is finding radon concentrations in homes exceeding its 4 pCi-per-L action level virtually everywhere, and it is impossible, according to the agency, to know which houses will have the higher concentration. The only way to find out, then, is to test every house. There are about 65 million houses in the U.S., and only a few thousand have been tested so far.

This proposal has created a lot of consternation. Basic questions about EPA's whole program have been raised: How valid are the kinds of readings EPA is taking? How accurate are these short-term tests? And are people being frightened by an overcautious agency not used to handling risks of this magnitude?

Inasmuch as most of EPA's tests so far have been just short screening tests in the basements of houses, there is some doubt whether these numbers should be used as a basis for making decisions about an entire house. EPA admits they should not. In its "Citizen's Guide to Radon," the agency says, "The screening

How to keep the working levels separate from the picocuries

Radon measurements are most often reported as either picocuries per liter or working levels. These units, although sometimes used interchangeably, are not equivalent. And in Europe, even different units, based on SI names, are used.

The curie is the unit of radioactive decay defined as 3.7×10^{10} disintegrations per second. A picocurie (pCi) is one trillionth of that. In SI units, nuclear disintegrations are measured in becquerels (Bq), where 1 Bq equals 1 disintegration per second, or about 27 pCi. For radon measurements, which are given as picocuries per liter of air, this means that each picocurie is about two radon atoms decaying per minute in a liter of air.

Picocuries are technically accurate for measuring actual radon gas concentrations. However, radon's half-life is less than four days, and it is radon's decay products that contribute more to the radioactive dose a person receives than the gas itself. To measure this, a new unit was devised for the underground miner studies, one that reflected the radioactive dose received from exposure. That unit is called a working level. It is the total energy deposited by all the subsequent decays of the radon daughter nuclei, and is defined at 130,000 MeV of alpha particle energy dissipated in 1 L of air. When equilibrium factors are included, the energy of 1 working level equals that from 200 pCi per L of radon progeny (but just 100 pCi per L for radon gas).

For simplicity's sake, the Environmental Protection Agency refers to the radon daughter number as radon concentration, because most of the devices used for home samplings actually measure the radon progeny concentrations. There is no SI equivalent of working level, but it works out to 3700 Bq per cubic meter or 2.08×10^{-5} joules per cubic meter.

Cumulative exposures to radon are measured in working-level months, which is defined, for the miner, as exposure to 1 working level over a 170-hour working month. For example, if a miner had been working for four months (at 170 hours each month) in an environment that had 20 pCi per L of radon progeny, he or she would be said to have accumulated 0.4 working-level month of exposure. Most scientific studies on the health effects of radon exposure use cumulative doses expressed in working-level months.

measurement is not a reliable measure of the average radon levels to which you and your family are exposed." And, although the agency says that a finding of high levels—that is, greater than 4 pCi per L—should be followed up with additional testing, this often isn't conveyed to the public in newspaper and television accounts of EPA suggestions.

Anthony V. Nero, a researcher for the indoor environment program at Lawrence Berkeley Laboratory of the University of California, Berkeley, thinks EPA is misinterpreting these data. "When EPA says that 20 to 30% of the homes exceed their action levels, most of these levels are just basement concentrations," Nero says. "And this is not what the action levels are all about." Guimond admits that using basement levels generally overestimates averages, but says "that is to give screening measurements that are conservative values in order to minimize false negatives." He adds that individuals with high values in their homes are encouraged in the EPA literature to ask for advice from state or local health officials who have been schooled in testing for radon. "Unfortunately, people don't read much of the stuff we hand out," Guimond admits.

Nero and other scientists, such as Bernard L. Cohen of the University of Pittsburgh, who are doing home radon measurements, think EPA's numbers are just too high. Instead of the 4 pCi-per-L average EPA is finding in basements, they conclude that average indoor radon levels, measured over the long term, are about 1.5 pCi per L. Nero's research finds that only 2% of the homes in the U.S. would have radon concentrations at or above 8 pCi per L, which he believes is a more realistic level at which to become concerned. In addition to this, Nero says his data show that the homes with the highest radon levels are tightly clustered. Disagreeing with EPA's call for all homes to be tested, Nero says it would be much more effective to identify the areas where radon concentrations are higher than normal and monitor the houses there.

Cohen's data have gained some notoriety because they show some effects contrary to what EPA says it has been finding. He has compiled radon measurements in homes in 411 counties in the U.S. that he claims show a negative correlation between indoor radon concentration and lung cancer. Using data from several state testing programs, from that he collected by sending out free testing devices, and from people who paid him to test their homes, Cohen says he consistently gets results that show lower levels of lung cancer than expected when low levels of radon are measured. In high radon areas of the U.S., for instance, where the usual risk estimates would predict a 200% increase in lung cancer for women, Cohen reports a decrease of 18%. Separately, when he compares the areas of the U.S. with the lowest and the highest female lung cancer rates, he finds that the radon levels are lower in counties with high lung cancer rates and higher in counties with low lung cancer rates.

EPA doesn't think these data can hold up to close scrutiny. Guimond says he is disappointed that, when dozens of investigators over the years conclude there is increased risk from radon exposure, this one contrary study is given so much attention. "Bernie, out of the blue, takes this one weak data set, he makes some back-of-the-envelope calculations and comes up with a theory that people are grasping at like crazy, like it's definitive." Guimond says some of the problems he sees with these data are that Cohen mixes various types of houses, does not use all randomly selected houses (EPA finds that people who choose to have their house tested for radon have higher levels than those selected randomly), and uses cancer death data from 1950 to 1969 in contrast to radon measurements taken from 1982 to 1988. Although Cohen's report tries to take these confounding factors into account, Guimond says one has to be very, very cautious about these kinds of general extrapolations.

Cohen says that one explanation for his results may be a combination of the linear, no-threshold theory of cancer formation with hormesis. Hormesis is the concept, roughly, that a toxic agent can have a beneficial effect on a body at levels below those at which harmful effects are produced. In the case of radon, some scientists believe there is a hormesis effect at low levels and that this is shown in Cohen's data. T. Don Luckey, retired professor of biochemistry and nutrition from the University of Missouri, Columbia, school of medicine, maintains that many health physicists are coming around to this position. "Low levels [of alpha radiation from radon] probably stimulate the body's defense mechanisms and you end up with less cancer," Luckey says. He says there are data showing this effect, especially with gamma or x-rays, but not much with alpha particles yet. Cohen mentions the hormetic effect in his research, saying that at low doses and low rates, hormesis is consistent with his data.

Some animal data show unusual effects from radon exposure. Cross at Battelle says at high levels of exposure there appears to be some concentration where radon daughters' ability to produce cancer is the most effective. Below that concentration, the cancer-causing ability seems to decrease. Certain animal data, Cross says, "suggest that there is a given exposure rate and a particular exposure level that is most efficient for producing cancer. And when you go down from that rate or up from that rate the efficiency of cancer production falls off. What we have to do is continue to work to see if, as we protract exposures to extremely low levels, we might be going to a no-effect level. It's way too early to say that, however."

Another interesting effect Cross mentions concerns the risk dependency of unattached radon daughters. "When unattached daughters are inhaled into the lungs, the deposition frequencies are 100%. When daughters that are deposited on dust particles in the air are inhaled into the lungs, only a few percent of them will be deposited along the trachial-bronchial surfaces where humans get lung cancer. Where this is important for indoor radon, as opposed to underground mines," Cross maintains, "is that you have much cleaner air in most houses. So one must consider unattached daughters when estimating the risk from indoor radon exposure."

The effect of smoking on lung cancer risk from radon is significant. The NAS radon study indicates that the risks from radon exposure are multiplied when the person is a smoker. The study admits, too, that the estimates of risk it makes may be more applicable to smokers than nonsmokers in general, because there are very few nonsmokers included in the lung cancer mortality data from underground miners. William Mills, a senior technical adviser for Oak Ridge Associated Universities in Washington, D.C., and past director of the criteria and standards division of EPA's Office of Radiation Programs, thinks the smoking factor has been way underplayed. "My biggest concern is that the risk to the nonsmoking population is much less than to the smoking population," Mills says. "Yet when you talk about average lung cancer deaths caused by radon in the U.S., it's weighted to the smoking population. The smoker is already at such high risk of lung cancer from the smoking, I'm not sure public policy should be based on what the risk to the smoker is." Some people believe that the lung cancer risk from radon is so high for smokers and so low for nonsmokers, that even if the radon concentration in all homes was lowered to less than 4 pCi per L there would be no noticeable drop in lung cancer death statistics.

Epidemiology studies under way at the National Cancer Institute may shed some light on the health hazard from radon in homes. One study to be completed this year involves 1600 women from New Jersey, half of whom had lung cancer. Another similar study is being carried out in Missouri, this one with 350 women with lung cancer who had never smoked. Two other international studies are being run at NCI. One is in Stockholm because of the very high radon concentrations found in that city; the other is in the city of Shenyang, China, because the highest rate of lung cancers in the country is found there. Data from these studies are expected to be available within a year.

Most researchers concur that radon in the home can be a problem. Levels in the 10 to 20 pCi-per-L range over a lifetime can equal the exposure that miners received where high lung cancer rates have been observed. There is some feeling, however, that EPA may have set its action level too low. Although nearly all studies agree that there is only about a 1% risk of getting lung cancer at 4 pCi per L, EPA may not be handling the concepts involved properly.

Berkeley's Nero says, "This is a much bigger risk than EPA is normally dealing with. They are not used to thinking in terms where an average risk is 1%. There is a real contrast between a situation where one is controlling a pollutant concentration in a common resource like the outdoor atmosphere and the kinds of risk people, knowingly or not, accept every day in their houses, cars, or workplaces. There, ordinary risk levels are higher and that's because those are the places we enclose ourselves, for our own benefit. The whole risk/benefit equation is completely different in those circumstances than it is when considering something like the outside air." As an example, Nero points out that people in a home with an average concentration of 1.5 pCi per L have about the same risk of lung cancer as they have of dying from an accident in the home. The excess risks are really to persons living in the 20 pCi-per-L and higher range, and that should be where EPA is concentrating its efforts, he says. ☐

Aromatics Price Increases Forecast To Ease

Catch-up of supply to demand is expected to diminish selling prices of benzene, toluene, and xylenes

Bruce F. Greek, C&EN Houston

A widely cycling relationship between supply/demand and price for major-volume aromatics—building blocks for a huge array of other chemicals—may be headed for another turning point. Strong demand, especially for benzene, carried over from last year and a few supply problems have pushed prices this month for benzene, toluene, and mixed xylenes to their highest levels in more than a year. Benzene, for example, currently is selling for $1.90 per gal on a contract basis, compared with $1.10 about six months ago. However, the current prices will be short-lived, according to industry sources.

Unless more plant problems crop up and export demand for aromatics derivatives spurts, supply will move closer to demand. Prices, particularly spot prices, may weaken during the second quarter. This month, sellers of benzene have noted that buyers are reluctant to take more product than is needed for immediate conversion to derivatives. Buyers also have noted that current prices are above levels needed to bring aromatics out of the gasoline pool at current gasoline prices at refineries.

Both the buyers of aromatics for nonfuel uses and the petroleum refiners are aware that aromatics prices could stay above last year's levels during the summer driving season. Refiners are expected to have to struggle to meet the anticipated volume and octane-value demand for premium unleaded gasoline. Premium gasoline currently has gained about three times the share of the total gasoline market expected by petroleum refiners, based on historical demands for premium gasoline.

Despite the demand that aromatics be left in the gasoline pool to give better octane value, output of aromatics by separation and purification from catalytic reformate and steam-cracking product streams will increase over 1988 levels. Benzene recovered from these streams, and other minor amounts from coking of coal and from styrene manufacture, will total more than 1.7 billion gal in 1989, up 4 to 5% from 1988 production, which is estimated to have been more than 1.6 billion gal. If 1989 benzene production does exceed 1.7 billion gal, it will top the all-time record output of 1.67 billion gal in 1979.

Output of toluene and mixed xylenes for nonfuel uses are likely to rise by about the same fraction. Toluene recovered from its sources for nonfuel uses is forecast to total more than 900 million gal in 1989. That output, however, will be less than the historical record of more than 950 million gal produced in 1987, according to the International Trade Commission.

This year, production of mixed xylenes (ortho, meta, and para isomers and a small quantity of ethylbenzene) is forecast to reach about 850 million gal. Forecasts of xylene production involve some uncertainty because variations in the feedstocks sent to reformers and steam crackers, and in the operating conditions of those units and extraction units, can change the aromatics product mix. This year's production of mixed xylenes will be well below the record level of more than 1 billion gal recovered in 1979.

Capacity to produce benzene, toluene, and xylenes far exceeds actual production. Some of those aromatics are contained in the feedstocks to reformers and steam crackers and may pass through processing unchanged. Conversion of other feedstock components to aromatics depends heavily on operating conditions, especially in reformers. Higher aromatics output can be obtained by increasing the severity of operation at the cost of greater loss of the feed. Currently, because of increased sales of higher octane gasoline, reform-

U.S. aromatics nonfuel supply/demand

Refineries provide 75% of U.S. nonfuel aromatics supply

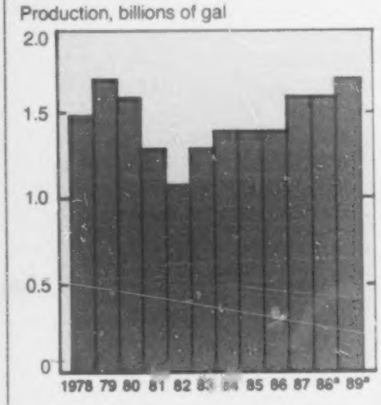
Source	Millions of gal
Catalytic reforming	2200
Steam cracking	675
Coal coking	50
Styrene coproduct	25
TOTAL	2950

Benzene accounts for one third of U.S. nonfuel aromatics demand

Aromatic	Millions of gal
Benzene	1100
Toluene[a]	900
Xylenes[b]	850
TOTAL[c]	2850

Note: Benzene, toluene, and xylenes only. **a** 575 million gal hydrodealkylated to benzene and disproportionated to benzene and mixed xylenes. **b** Ortho, 80 million gal; meta, 15 million gal; para, 750 million gal; remainder consumed as mixed xylenes, mostly as solvents. **c** Balance of exports over imports accounts for difference. **Source:** C&EN estimates

Benzene output will hit decade-old record



a Estimate. **Sources:** International Trade Commission, C&EN estimates

ers are being operated under more severe conditions than during the mid-1980s and are producing more aromatics.

Steam crackers currently are being operated to maximize ethylene production. As a result, feedstocks have been shifted toward light hydrocarbons wherever possible and the output of pyrolysis gasoline containing aromatics is thereby reduced. However, because steam crackers account for a small part (3 to 5%) of total aromatics production, the present changes have only a small effect on total aromatics production.

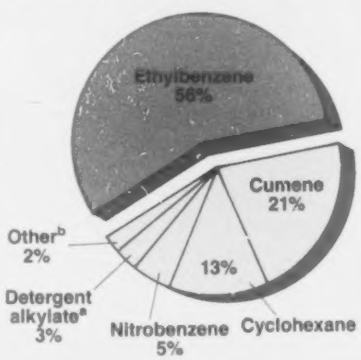
For chemical and other nonfuel uses, aromatics are removed from reformate and pyrolysis gasoline by solvent extraction. Benzene, toluene, and xylenes are then separated and purified, and the remaining components are returned to the gasoline pool. Recovery and purification capacity also exceeds demand for aromatics by a substantial amount. However, if feed to a catalytic reformer is limited in volume or in aromatic precursors and if operating problems exist with the reformer, then aromatics in the reformate can be down and recovery low.

Of the three major commercially significant aromatics that are chemical raw materials, toluene has the least use, other than for conversion to benzene. About two thirds of toluene removed from aromatics sources is converted to benzene, largely through hydrodealkylation (HDA). Currently, toluene HDA accounts for roughly a third of benzene production, but it has been in the range of 20 to 30% of production on average during the period between 1975 and 1985.

The share of benzene produced from toluene also will vary widely with selling prices of the two aromatics. At this time, with benzene prices about 60 cents per gal higher than toluene (now about $1.30 per gal), most operable HDA units are running profitably. The spread between benzene and toluene prices determines whether HDA units will operate. The spread covers processing costs and the difference in value of toluene in other uses, particularly in gasoline. Startup and shutdown of HDA units are done with relative ease and low cost, making the use of these units sensitive to prices.

Part of the rapid increase in the spot benzene price during the fourth quarter of 1988 and the contract price more recently has resulted from a slow restart of HDA units and the problems occurring after the units began operation. Last summer, benzene and toluene prices were so close that many HDA units couldn't be run profitably. Prices of both of these aromatics then began to rise, but their price difference remained small enough that HDA units were not restarted. Late in the third quarter, demand for benzene use in its three major derivatives—ethylbenzene (for styrene), cumene (for phenol), and cyclohexane (for nylon)—strengthened rapidly, driving prices higher. The delay in getting HDA units started because of the unacceptable selling price differential led to apparent shortages of benzene, resulting in even more price increases. As HDA units were started up, a few experienced mechanical problems. Other units had feedstock limitations because of problems in reformers and in aromatics extraction and purification units providing the toluene feedstock.

Ethylbenzene dominates chemical uses of benzene



1988 total use = 1.69 billion gal^c

a Mostly linear alkylbenzenes. b Mostly chlorobenzenes. c Includes 60 million gal excess of imports over exports. **Sources:** International Trade Commission, C&EN estimates

So far this year, contract prices for benzene have followed spot prices, suggesting that supply is still lower than demand. Change toward a balance hinges on the largest use of benzene—that of making styrene—according to industry sources. An unusually strong demand growth for polystyrene in 1988, with production up more than 8% through October over 1987, now is forecast to ease because polystyrene capacity has become fully utilized.

Styrene production growth closely matched that of polystyrene for the first nine months of 1988. Some debottlenecking of capacity has occurred and is forecast to continue this year, to add 3 to 5% to capacity. Demand for benzene in this use will rise this year by about half of the growth last year, easing the supply pressure temporarily. However, a large amount of new styrene capacity will be coming on stream in 1990, to add more than 1 billion lb of capacity to the current total of about 8.5 billion lb. That additional styrene capacity will require about 100 million gal more of benzene during 1990.

Both other major uses of benzene—cumene and cyclohexane—grew more slowly last year than ethylbenzene. This year, cumene use is forecast to grow slowly, mainly because of expected lower demand for resins used in plywood and particle board, resulting from lower housing construction. Housing is expected to affect cyclohexane growth similarly, holding down growth in this use of benzene. □

Hazardous Waste Management Database Starts To Take Shape

Survey provides data on waste treatment, storage, disposal, and recycling; survey on hazardous waste generation also under way

James Krieger, C&EN Washington

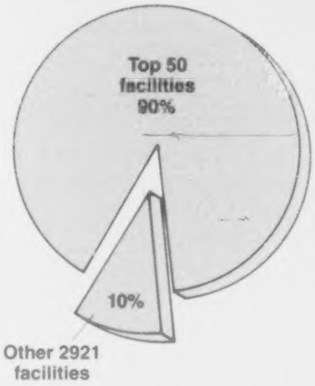
AAAS SAN FRANCISCO

When Research Triangle Institute personnel have finished tabulating the results of two recent surveys later this year, the Environmental Protection Agency will have a comprehensive database for the 250 million to 600 million metric tons of hazardous waste generated annually in the U.S. That database will provide the underpinning for regulatory development under the Resource Conservation & Recovery Act of 1976 (RCRA) and related legislation.

Overall, the effort is a large, multiyear, interdisciplinary project. It is being conducted by the Research Triangle Park, N.C., institute under contract to EPA's Office of Solid Waste and is designed to collect data on the nation's generation and management of hazardous waste.

The survey on management—which covers facilities for treatment, storage, disposal, or recycling (TSDR)—is the first to bear fruit. Preliminary survey results were the focus of a symposium at the annual meeting of the American Association for the Advancement of Science last month. Providing an overview of how the survey was developed and implemented was an EPA-RTI project team headed by EPA project officer James W. Craig and RTI project manager John L. Warren, and including RTI's Danny R. Allen, project computer operations manager; Patricia C. Smith, survey operations manager; and Sheryl A. Caldwell, who was in charge of survey questionnaire development.

Large facilities manage most of the waste



Total waste managed = 272 million metric tons

Between now and June, the schedule for the TSDR survey calls for computer edits, followup, and cleanup of the data, with creation of the final database system slated for July and August. A report with final data likely will be available this summer. The hazardous waste generator survey is ongoing as well, with a final report due late this year.

Meanwhile, the TSDR facility data presented at the symposium, Warren notes, have not been completely edited and reviewed. As a result, numbers are provided for now in ranges rather than point estimates.

As covered by the survey, hazardous waste includes a variety of categories—any waste considered hazardous by RCRA; any waste considered hazardous by a state; any waste considered hazardous in the state in which it is generated, even if it is not considered hazardous by the state in which it undergoes treatment or disposal; wastes containing polychlorinated biphenyls; wastes containing asbestos; and wastes containing dioxins.

More than two years in development, including pretesting and site visits, the TSDR survey was detailed and comprehensive. The survey questionnaire was mailed out in August 1987, and the full package consisted of 15 different booklets. There was a booklet for each technology used for managing hazardous waste. More than 700 questions and 5000 variables were used to organize the data collected from 2626 TSDR facilities. RTI used computer systems to manage the survey, enter the data, edit the data, and analyze results.

The information requested from survey respondents included general facility information and waste management process regulatory status, commercial availability, and design and operating parameters.

Industrial organics is highest class in hazardous waste volume

Standard industrial classification	SIC category	Hazardous waste volume, millions of metric tons
2869	Industrial organic chemicals	60–80
2800	General chemical manufacturing	40–50
2911	Petroleum refining	20–30
2892	Explosives	10–15
2821	Plastic materials/resins	6–10
4953	Refuse systems (commercial TSDR[a] facility)	5–8
2879	Agricultural chemicals	5–8
2865	Cyclic crudes/intermediates	5–8
2816	Inorganic pigments	3.5–5
2812	Alkalies/chlorine	2.5–4.5

[a] Transportation, storage, disposal, or recycling.

Various technologies are used in hazardous waste management

Type of technology or process	Waste volume managed, millions of metric tons
Incineration	0.85–0.95
Reuse as fuel	1–1.2
Fuel blending	0.45–0.6
Solidification/stabilization	0.5–0.6
Solvent recovery	0.7–0.8
Metal recovery	0.4–0.5
Wastewater treatment	350–450
Other treatment processes	1.5–3
Waste pile	0.4–0.5
Surface impoundment	150–225
Landfill	1.7–2.0
Land treatment	0.3–0.4
Underground injection	11.5–13.5

Additional information requested included waste management capacity, planned changes in management capacity, waste quantity and type generated and managed, and tank system design and operating parameters.

As surveys go, the TSDR survey was unique in many ways. For one thing, EPA should eventually receive 100% response, since respondents are required by RCRA to furnish the information, with fines of up to $25,000 per day possible for nonresponse. However, facilities did have a further incentive to respond—namely, seeing that EPA has information that is accurate for use in developing regulations.

Another unique aspect of the survey is that respondents were guaranteed confidentiality by law. Hence, because of the nature of some of the data being collected, some responses are claimed as EPA confidential business information. Based on EPA requirements, RTI installed a minicomputer (VAX 11/750) dedicated to the hazardous waste surveys to provide secure management of confidential data. According to Warren, the computer facility is the largest of its kind outside EPA that is approved for managing confidential data collected under RCRA.

The nature of the responses adds still further to the uniqueness. EPA considers a respondent's completed questionnaires to be an official legal record of the operations at that facility. Most surveys ask respondents simply to complete questions to the best of their ability. But EPA expects the facilities to portray their operations accurately, because EPA needs reliable data to defend itself against lawsuits filed to overturn or stay regulations developed using the data.

The survey was lengthy, and it was complete. The entire set of questionnaires added up to more than 500 pages. The technical nature of the requested information required many complex questions. Moreover, unlike previous surveys of hazardous waste management, the TSDR survey requested information not just on the highest volume wastes or largest facilities. It required respondents to provide information on every hazardous waste stream, every hazardous waste management process, and every hazardous waste management unit.

A feature of RTI's approach to the survey is the development of two respondent support systems, a toll-free Survey Helpline and a newsletter called *Survey Update* mailed periodically to surveyed facilities. The Survey Helpline was a network of five WATS telephone lines and six trained personnel operating five days a week. RTI's Caldwell notes that during the first two months of operation, the helpline received about 300 to 400 calls per week. Toward the end of the response period, the number of calls dropped to less than 100 per month.

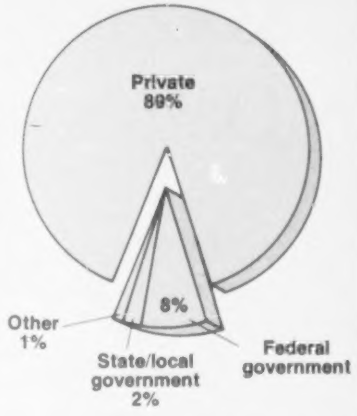
During the survey, three issues of *Survey Update* were mailed. The topics addressed by the newsletter included those relating to major elements of the survey, recurring issues and questions on Survey Helpline, and errors noted in the questionnaires.

Industrial organics class has most management facilities

Standard Industrial classification	SIC category	Number of TSDR[a] facilities
2869	Industrial organic chemicals	150
2911	Petroleum refining	96
9711	National security	85
4911	Electric services	63
2821	Plastic materials/ resins	57
2819	Industrial inorganic chemicals	54
3471	Plating and polishing	45
4953	Refuse systems (commercial TSDR facility)	45
2491	Wood preserving	44
3312	Blast furnaces/ steel mills	37

[a] Transportation, storage, disposal, or recycling.

Most waste management facilities privately owned



Total number of facilities = 2971

The TSDR survey has had a long gestation period. Originally, EPA planned a less extensive survey to support analyses of hazardous waste regulations developed under RCRA. However, EPA's information needs changed significantly with passage of the Hazardous & Solid Waste Amendments of 1984 and the Superfund Amendments and Reauthorization Act of 1986 (SARA).

EPA's Craig explains that the 1984 amendments required new regulations, beginning with restrictions on land disposal of hazardous wastes, and significant modifications to existing regulations, such as revising the ways to determine if a particular waste stream is hazardous. Included in other requirements were the development of standards for managing hazardous wastes in tanks, for cleaning up contamination caused by waste management units, and for performing economic and risk analyses of any regulations developed.

Realizing it needed additional information for aspects of waste management affected by the new legislation, EPA expanded the scope of the initial survey. It increased the size of the survey's universe from 700 facilities to 3000 to support development of regulatory standards as well as economic and regulatory impact analyses.

Then in November 1986 came SARA, which requires states to assess the available capacity for managing hazardous wastes and to site new facilities where needed. As a result, EPA needs to estimate available capacity by state. So the survey sampling plan was stratified by state as well as by type and size of management process.

Craig notes that in addition to using the survey for regulatory development, EPA will use the data for trend analyses, for planning, and for targeting enforcement actions, although no enforcement actions will be undertaken solely on the basis of questionnaire responses. For regulatory development, the data will provide a basis to evaluate capacity available to manage hazardous waste using technologies other than land disposal; develop efficiency standards for waste management technologies used as alternatives to land disposal; develop permitting standards for tanks used to manage hazardous wastes; revise procedures for identifying wastes as hazardous; develop standards for cleaning up contamination caused by waste management units; assess costs, risks, and impacts of hazardous waste regulations; and evaluate each state's plans to provide sufficient capacity to manage hazardous waste. ☐

Chemical warfare organization debated

Two policy analysts with the U.S. Institute of Peace propose that an International Chemical Warfare Authority be set up as a means of short-circuiting what they perceive as flaws in current negotiations in Geneva on a global ban on the possession, production, and use of chemical weapons. If such a global ban is feasible, which they question, it will not be negotiated for several years. In the interim, they offer their proposal as one possible way of stemming the spread of chemical weapons.

As envisioned by Robin Ranger and Raymond Cohen, both Jennings Randolph Peace Fellows at the peace institute, the authority would consist of:

C&EN staff photos

Ranger: unenforceable limits

- A governing council of member states, composed initially of the two superpowers and major industrial nations.
- A permanent secretariat.
- An inspectorate, which would investigate charges of violations. It would not necessarily be linked to the United Nations. It would monitor worldwide flows of precursor chemicals and chemical weapons-making equipment. And it would have chemical weapons and equipment for defensive and offensive purposes at its disposal, which it could supply to states victimized by chemical warfare.

Ranger and Cohen presented their proposals for critique at a workshop sponsored by the institute in Washington, D.C., late last month. They used the public forum as "a heuristic device," Ranger said, and a means of provoking "fresh thinking in a debate that has stagnated," Cohen added. Their proposal met with only mild acceptance.

The analysts are trying to carve out a middle ground between a global treaty completely banning these weapons, and independent policies of deterrence. "Politically and practically speaking the basic proposal is a nonstarter," says Brad Roberts, executive editor of *The Washington Quarterly* and an invited discussant.

Underlining the raison d'être for the proposal, Ranger cites recent outbreaks of chemical weapons use as illegal breaches of the 1925 Geneva Protocol. This leads him to distinguish between the ability to verify such breaches and the inability to enforce compliance with such a longstanding treaty.

Following the logic of his thinking, Ranger asks if it is "feasible to negotiate limits on chemical and biological weapons which cannot be enforced?" He answers, in part: "If the U.S. and its allies find that they cannot enforce a ban on the first use of chemical weapons, then it is difficult to say how they would expect to enforce compliance with a ban on the manufacture and production of chemical weapons." The ongoing talks in Geneva are trying to develop a global, verifiable ban on the production and possession, as well as use, of chemical weapons.

Elisa D. Harris, a guest scholar at Brookings Institution and another discussant, finds it "useful to distinguish between compliance and verification." But she says, "It is important not to exaggerate or overstate" breaches in compliance.

"One could argue that there have been remarkably few violations of the Geneva Protocol," Harris continues. She notes that there have been about 200 conflicts since World War I when chemical weapons could have been used and were not,

Harris: only five confirmed violations

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Trade issues piling up for the U.S. chemical industry Page 9

FINAL PROGRAM ACS national meeting in Dallas Page 43

FEBRUARY 13, 1989
CHEMICAL & ENGINEERING
NEWS

FOSSIL FUELS

Biotechnology applications possible
in processing, conversion
Page 28

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News of the Week

- **Illinois Supreme Court rules that Occupational Safety & Health Act of 1970 does not preempt the state from criminal prosecution of employers charged with workplace violations.** Page 6

- **Scientists have produced an antibodylike molecule that is a good candidate for therapeutic use in AIDS patients.** Page 7

- **DowBrands Inc., a subsidiary of Dow Chemical, has signed an agreement to purchase the European consumer products business of First Brands Corp.** Page 7

- **The Strategic Defense Initiative seems likely to be replaced by a more limited ballistic missile defense system.** Page 8

- **Report asks Bush Administration to loosen restrictions on export of high-technology products and scientific information.** Page 8

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Letters 4

Concentrates
Business 15
Government 21
Science/Technology 27

The Departments
Books 39
New Products 119
Newscripts 150

News Focus

Chemical industry currently faces more than the usual number of knotty tariff reduction problems, other trade issues. **Page 9**

Business

Many venture capitalists are reluctant to invest in commercializing high-temperature superconductors because payoff is uncertain. **Page 17**

Chemical groups assess their suspension policies in light of recent suspension of Imhausen Chemie by West German association. **Page 19**

Government

NSF director Erich Bloch, now in the final year and a half of his current term, discusses current science policy issues. **Page 22**

EPA's Superfund program is criticized in three recent reports. **Page 24**

Technology

Fast-curing, stronger cement that can be poured in cold weather is developed by Lone Star Industries. **Page 37**

ICI Biological Products takes a major step toward expanding its biotechnology business. **Page 38**

ACS News

Rodney N. Hader retires as secretary and deputy executive director of ACS, ending 38-year career in various staff posts. **Page 41**

Final Program

Program for 197th ACS national meeting in Dallas includes listing of technical papers, general events, registration form. **Page 43**

Cover Story

Symposium explores possible applications of biotechnology in processing and conversion of fossil fuels. **Page 28**

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LETTERS

Explosives detection

SIR: With respect to the December Pan American flight 103 air disaster and the findings that it was caused by a bomb, I believe ACS (and all professional societies worldwide) should join in establishing explosives detection standards.

I remember a letter to the editor in C&EN several years ago suggesting the inclusion of a mercaptan or similar compound that could be detected easily by security dogs. I believe ACS should encourage a policy that aids in "fingerprinting" explosives. This fingerprint could be read by a dog's nose or a high-tech computer. This is a problem in which the scientific community should take an active stance.

Scott Kuhn
Houston

Peptide hydrolysis

SIR: A science concentrate (C&EN, Nov. 7, 1988, page 17) describes Clark Still's accomplishment in measuring the rate of peptide hydrolysis in pure water. In the paper describing that work [*J. Am. Chem. Soc.*, **110**, 7529 (1988)], the author comments that the simple hydrolysis of an unactivated amide has never been observed in pure water.

It should be noted that the late Jack Hine of this department reported the pH-rate profile for just such a hydrolysis reaction in his paper, "Hydrolysis of Formamide at 80 °C and pH 1-9" [*J. Org. Chem.*, **46**, 3186 (1981)], in which the water term in the rate equation was determined for the first time. The radioassay utilized in Still's group permits rates to be determined at room temperature, which was not feasible in the Hine study.

Anthony W. Czarnik
Assistant Professor
of Chemistry
Ohio State University

Labeling technology

SIR: I have been fascinated as to how rapidly our retail merchandisers have adopted bar coding to monitor inventories, receiving, sales, and so on. One can hardly go anywhere without encountering that labeling, which purportedly can be used to help reduce transcription errors, speed various tracking activities, and reduce costs in processing information on thousands of items.

Fortunately, one can go to any high-tech chemistry laboratory to escape this labeling invasion. We are safely ensconced amid tens of thousands of reagent bottles, column materials, and supply items that are labeled as they have been for decades, so that only skilled, knowledgeable chemists can track them. Our supporting industries also have helped to protect our historical information systems and reduce the impact of this technology by mounting serial and model numbers in nonmachine readable forms usually at the rear of our instruments.

If it turns out that this labeling technology is more than a passing social fad, perhaps we, in the not too distant future, will see bar-coded labeling on our containers, catalogs, and front-mounted on our instruments. If that goes well, perhaps we will find some of our catalogs on disks with full word search capability, purchasing instructions, and dial-up features on board.

Thomas Layloff
Granite City, Ill.

Explaining reality

SIR: In reply to the question in the letter of David E. Hensie (C&EN, Sept. 26, 1988, page 73), modern science cannot answer the question, "What is reality?"

We of modern science are indebted to Galileo, 16th century physicist, mathematician, philosopher, and father of the math-experimental method we so eagerly use. The appeal of the positive proof of the method fascinated the philosophers (scientists) of his day. He cautioned them that the method was "applicable only to those areas of knowledge possessing measurable properties and inapplicable to those areas with no measurable properties such as religion, ethics, psychology, and metaphysics." Ignoring his admonition, his peers applied the method to the study of such concepts as being, existence essence, truth, cause/effect, and the reliability of sense perceptions. Chaos resulted and philosphy was divided into natural philosophy, the forerunner of modern science, and into speculative philosophy, the tool vital for the pursuit of truth.

This schism has led to the domination and application of the method of science to every domain of knowledge today whether it is applicable or not. Verification of facts and exhaustive experimentation are vital to theory and are the bases of physical science. How the resulting scientific knowledge affects or effects humanity's search for ultimate

Chemical Industry Tackles Hefty Number of Trade Issues

Tariff reductions in Uruguay round, speedier tariff cuts under U.S.-Canada free trade agreement, and unified European Community in 1992 lead list of problems facing industry policy makers

Earl V. Anderson, C&EN Northeast News Bureau

The few trade policy professionals who help shape that policy for the chemical industry constantly scan the corridors of bureaucratic Washington watching for developments in U.S. trade policy. With a two-way chemical trade that hit a hefty $52.6 billion last year (exports of $32.5 billion and imports of $20.1 billion), they know that any development in the trade arena can affect most U.S. chemical companies.

These trade policy experts always have their work cut out for them. But sometimes, they have to work harder than normal, fighting tough deadline pressure and struggling with several issues simultaneously.

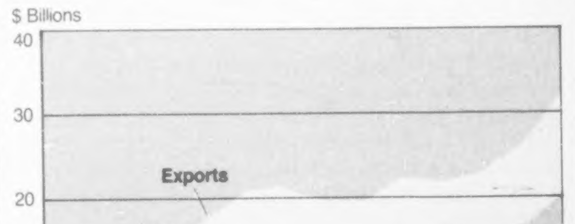
Now is one of those times.

For instance, the International Trade Commission (ITC) already has started to hold a series of hearings in many cities throughout the country on the probable economic effects of tariff and nontariff barrier concessions that U.S. negotiators may make in the Uruguay round of multilateral trade negotiations. The problem is, however, that many U.S. chemical companies aren't even aware that the hearings are being held. And trade policy experts in the various industry trade associations are not only trying to get the word out about the hearings, but also are trying feverishly to help some companies whip their testimony into the shape that will do the most good.

Meanwhile, just when everyone in the industry thought that they could ease up on their efforts to shape industry policy on the U.S.-Canada free trade agreement, which went into effect on Jan. 1, the U.S. Trade Representative's (USTR) office has come up with a rush request for additional input. Under the agreement, tariffs on some products are scheduled to be eliminated immediately. Others will be phased out, either by annual cuts of 20% over five years, or by annual cuts of 10% over 10 years.

However, the free trade pact allows for accelerated tariff cuts on products if both countries agree to the speedup. USTR is looking for candidates for the speedier tariff action. But the office put its notice in the *Federal Register* a scant three weeks ago and set a tight deadline of Feb. 21 for submission. That doesn't give chemical companies—or their trade associations—much time to pull their possible candidates out of the lengthy new harmonized tariff schedules (HTSs) that the U.S. adopted, also on Jan. 1, and to muster the data needed to support their case.

Those are only two of the things that the shapers of chemical industry trade policy are trying to juggle at the same time. USTR also intends to hold hearings on the economic consequences of tariff reductions that may be made in the Uruguay round, the mammoth multilateral trade talks being held under the auspices of the General Agreement on Tariffs & Trade (GATT). The products that USTR has identified as possible grist for the tariff-cutting mill cover virtually the entire product waterfront, including 616 line items in



U.S. chemical trade surplus has widened

a C&EN estimates. Source: Bureau of the Census the tariff schedules that relate to chemicals. Since many of those line items are so-called basket categories with from several to many products in each one of them, the number of chemicals that U.S. companies may have to evaluate is mind-boggling.

USTR hasn't announced when it will hold its own hearings on the economic impact of possible Uruguay round tariff cuts. The betting is that they will come soon after ITC finishes its hearings and submits its report to USTR.

And, as if the Uruguay round and the free trade agreement with Canada weren't enough, the chemical industry is also gearing up to tackle another thorny trade issue—the European Community's (EC) plan to create a unified EC internal market by 1992. Without minimizing the importance of GATT's Uruguay round or the U.S.-Canada free trade pact, chemical industry trade leaders emphasize that what has become known as "EC-92" is a critically important trade issue for U.S. chemical companies.

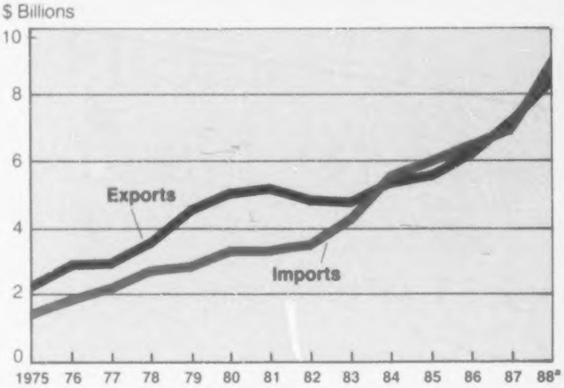
EC-92 has blossomed into the latest buzzword in trade circles. It is the subject of choice for many business meetings. For instance, the Conference Board, the New York City-based business research group, recently devoted a meeting to the subject. Other organizations, such as the U.S. Chamber of Commerce and the National Association of Manufacturers, are busy cranking out reports on EC-92. Meanwhile, the Synthetic Organic Chemical Manufacturers Association (SOCMA) and the Chemical Manufacturers Association (CMA) are canvassing their members to ferret out what chemical companies themselves may consider as stumbling blocks to success in a unified EC.

Some government agencies already have taken action relative to EC-92 and others are preparing to act. The Commerce Department has been following EC-92 progress closely, zeroing in on, among other things, EC's new approach to developing standards. Commerce has been holding briefings on EC-92 for industry trade advisers, including those from the chemical industry. Now, at the request of the House Ways & Means Committee and the Senate Finance Committee, ITC is preparing a study and will hold hearings on the impact of greater EC economic integration in April. According to John Gersic, chief of ITC's energy and chemicals division, "This one is a biggy."

Just what is EC-92? It is nothing more than another EC attempt to achieve full economic integration, which was one of the original goals of the 1957 Rome Treaty. After some early successes—a common agricultural policy, later a common fisheries policy, and a customs union with a common external tariff—progress toward complete economic integration ground to a halt.

The problem was that many EC member countries couldn't bring themselves to sacrifice any more of their national sovereignty. Now, after suffering through their economic problems of the late 1970s and early 1980s, EC countries believe that the only way that they can position themselves to compete against the U.S. and Japan in the global marketplace is to try once more for their elusive unification.

Chemical trade with European Community: U.S. imports more than it exports



a C&EN estimates. **Source:** Bureau of the Census

The target date for achieving this single internal market is the end of 1992. It will involve rewriting and harmonizing hundreds of individual country laws, regulations, and policies. What comes out of this effort will affect trade and investment decisions on thousands of products.

The EC effort will affect U.S. companies doing business in the community just as much as, if not more than, the European companies themselves. In the U.S., at least in some of the media, screeching about EC-92 is becoming louder and louder. Headlines warn about a "Fortress Europe" and a "protectionist entity" in 1992. Sir Roy Denman, head of the EC delegation in the U.S., says, "Anyone would think that [EC] was transforming itself into the big bad wolf of world trade in the 1990s." He, of course, doesn't think that's the case and he believes that saner business heads in the U.S. don't think so either.

Nevertheless, there's a healthy concern in the U.S. about what happens in EC's drive toward 1992. U.S. chemical companies share that concern. And for good reason. The 12 EC countries account for 26% of U.S. chemical exports and a whopping 44% of its chemical imports. Two-way chemical trade between the two trading partners last year totaled $9.4 billion.

Generally, the U.S. chemical industry supports EC's efforts toward 1992. But, says CMA, U.S. chemical companies have to watch carefully as many of the directives needed to launch EC-92 are developed. Whereas EC-92 may provide terrific marketing opportunities for U.S. chemical companies, it also could be structured to discriminate against outsiders or to put foreign companies at a disadvantage.

U.S. chemical companies will have to examine the implications of EC-92 from two different perspectives: a U.S.-based multinational company with substantial operations in Europe and a U.S. company that exports to Europe. For European subsidiaries of U.S. chemical companies, the impact should be about the same as for their strictly European counterparts. And CMA thinks that the European-based chemical industry will come out a winner when EC-92 is fully implemented. The expected lift to economic growth likely will boost chemical sales. And EC-92 will make it possible for European chemical companies to rationalize production and improve efficiency.

But U.S.-based chemical exporters will be able to share in the promise of a revitalized European market if they are allowed to compete on an equal footing with their European counterparts. As a result, their concerns about EC-92 parallel those of European companies, but they run deeper.

Technical standards, for instance, could be a problem. Although they are being harmonized in EC, exporters still will have to meet the standards in the country of entry. It's possible, too, that some standards may discriminate against U.S. exporters. New packaging and labeling requirements could become a problem.

Some industry trade associations, such as CMA, are asking their member companies to develop a "watch list" of potential trouble spots. They are reminding them not to overlook their European subsidiaries as a source of information. And they are keeping close tabs on developments by their connections with counterpart organizations in Europe.

So far, CMA has come up with no definitive policy statements on EC-92. But when the time comes to funnel private-sector advice into government channels, it expects to have specific recommendations.

Meanwhile, SOCMA chairman John Mack already has asked the new Bush Administration "to get America more involved in the debates" over EC-92. He doesn't want the U.S. chemical industry to wake up to a fait accompli that will endanger its export prowess. Mack recognizes that the U.S. can't tell its allies what to do. But, he says, "We can tell them what we will do in certain situations."

EC-92, however, is still three years away. A more immediate concern for chemical companies is next week's deadline for filing their wish list of products to receive accelerated tariff cuts under the U.S.-Canada free trade agreement.

Although not in the same league as EC, Canada nevertheless is an important part of the U.S. chemical industry's trade picture. With $3.9 billion worth of chemicals going north of the border from U.S. plants, Canada is almost as big a customer for U.S. chemicals as Japan. As a foreign chemicals supplier, it is bigger than Japan. Canada shipped $3.8 billion worth of chemicals to the U.S. last year, second only to the combined strength of the 12 EC member countries.

In addition, the chemical industry worked as hard as any to help government trade officials shape the free trade pact. So now USTR's quick call for possible alterations to the agreement's recently arranged tariff structure is bound to pique the industry's interest.

Under the agreement, tariffs on all products traded between the two countries will be completely eliminated. Some became duty-free on Jan. 1. Tariffs on other products will be completely phased out, either over five years or 10 years. However, if one country requests it and both countries agree, tariffs on selected products can disappear faster than originally planned. For instance, the two countries may agree to reduce the staging period on some products from 10 years to five years. On others, they may agree to eliminate immediately tariffs that were to disappear over five years.

Two aspects of the accelerated tariff phaseout trouble the chemical industry. One is the tight deadline; the other is that the U.S. and Canadian governments may agree to accelerated staging on products that are not "noncontroversial."

Throughout the negotiations over the free trade pact, the U.S. chemical industry's unflinching position was that any accelerated tariff phaseouts must be

UPI/Bettmann Newsphotos

Denman (left): EC won't become big bad wolf of trade world. Turnipseed (above): lack of interest may backfire. Hill: not much time to formulate plan

noncontroversial and that the standard for determining what is and is not noncontroversial must be the same as the one Congress applies when it considers temporary duty-suspension bills.

CMA, at least, believes that candidates for accelerated tariff phaseout must originate in the private sector, not in government. The free trade pact, it says, is a balanced agreement and its tradeoffs have been carefully crafted. If the two governments agreed to controversial tariff accelerations, they would undermine the pact's "fundamental balance." CMA's basic stance is that if any company objects to a proposal for accelerated tariff cuts, the proposal should be rejected.

Despite the tight deadline, the steps that USTR has taken to seek private-sector advice sits well with the chemical industry. And, although there may be a few, it's not likely that U.S. chemical companies will submit many chemical candidates for accelerated tariff phaseout. The free trade agreement itself is very new. If such candidates had existed, they already would be part of the product category whose tariffs went to zero on Jan. 1. However, most chemicals were put into, and remain in, the five-year category.

Still, the U.S. chemical industry will be watching closely the products that Canadian chemical companies put up as candidates for accelerated tariff elimination. The Canadian chemical industry, of course, is going through the same procedure with its government that the U.S. industry is. U.S. chemical trade experts suspect that Canadian chemical companies may propose some or all of the 26 major petrochemicals that had been their candidates for free trade very early in the negotiations, when "sectoral" free trade still was being considered. If this were to happen, it would be far from noncontroversial, at least from the U.S. industry's point of view.

The tariff question, of course, goes beyond just the U.S.-Canada free trade pact. The U.S. chemical industry still has to cope with the question of possible tariff cuts in GATT's Uruguay round of multilateral trade negotiations (MTN), which involves more than 90 member countries.

The industry's position on MTN tariff cuts has been made loud, clear, and often to U.S. trade negotiators. The message: Don't give away the store. Inevitably, GATT negotiators will include tariff reductions in the Uruguay round. But the chemical industry doesn't want them to be the focal point of the negotiations. The main thrust, it insists, should be on nontariff barriers to trade.

But if tariff cuts are to be made, say industry trade advisers, they should be made on a "request and offer" basis, that is, if one country requests that another country cuts tariffs on a particular product, the first country will respond with a specific tariff-cutting offer of its own.

As outlined by the Office of the Chemical Industry Trade Adviser (OCITA), U.S. trade negotiators definitely should not succumb to a "formula" or "across-the-board" tariff-cutting scheme. And they should propose tariff reductions only if the reciprocal offer enables U.S. companies to improve access to foreign markets.

But these are broad policy statements. Chemical companies are interested in products and what happens to tariffs on specific products. Companies now have their chance to express their views at the series of hearings that ITC currently is holding at many cities throughout the country. Five hearings should have been held by now. Two (New Orleans and Miami) were canceled because nobody expressed an interest in coming. No chemical companies signed up for the other three, either.

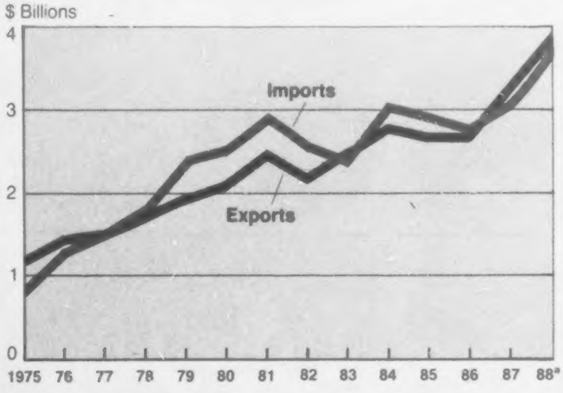
ITC has another 10 hearings scheduled between now and April 3 and 4, when the last hearing will be held at ITC's headquarters in Washington, D.C. So far, only one chemical company—Ethyl Corp.—has indicated that it wants to testify. It has signed up for the last hearing in Washington.

CMA also has requested a time slot at the Washington hearings. Its testimony will focus on how U.S. chemical companies may be affected by any changes in tariffs—and nontariff barriers—that may come out of the Uruguay round. However, CMA will be covering the entire chemical spectrum, which ranges from chapters 29 through 40 in the new HTSs.

It's up to individual companies to provide the necessary economic and marketing data to support its claim that a product may be import-sensitive and should be exempted from any possible tariff cuts. Clearly, companies haven't been forming long lines to sign up for the ITC hearings that will enable them to do just that.

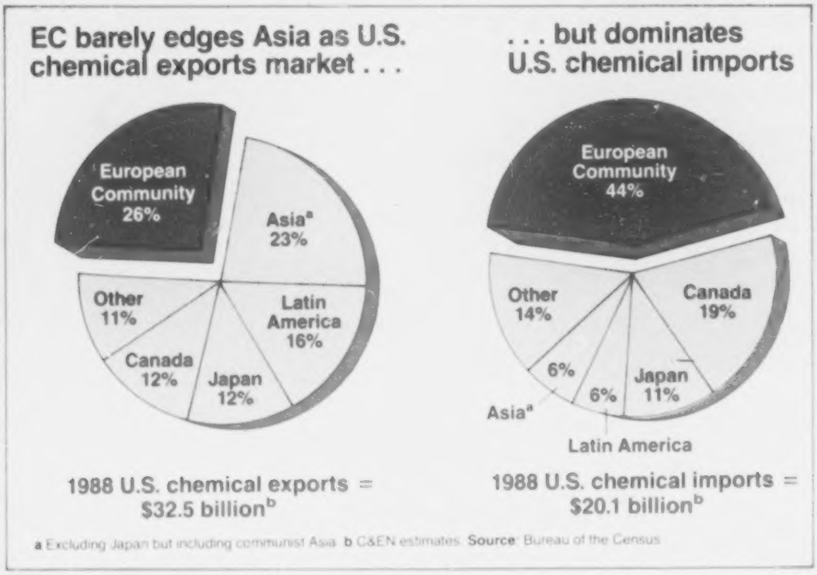
This has CMA concerned. Max L. Turnipseed, manager of international trade affairs for Ethyl Corp. who is also serving temporarily as CMA's special trade adviser, says that this seeming lack of interest may backfire on the industry.

One explanation for the chemical no-shows at the ITC hearings is that chemical companies can make written submissions to ITC instead of testifying in person, and they have until April 13 to do it. That



U.S. chemical trade with Canada edges into black

a C&EN estimates. **Source:** Bureau of the Census



EC barely edges Asia as U.S. chemical exports market . . .

. . . but dominates U.S. chemical imports

1988 U.S. chemical exports = $32.5 billion[b]

1988 U.S. chemical imports = $20.1 billion[b]

a Excluding Japan but including communist Asia. b C&EN estimates. **Source:** Bureau of the Census

gives companies more time to prepare their data. And it avoids the time and expense of sending their top management to give testimony at a hearing.

Officially, written submissions carry the same weight with ITC and other government trade agencies as oral testimony. However, human nature has a way of creating a bias against no-shows. Of course, no one will say for the record that this is what happens. But those familiar with the workings of official Washington know that it does.

That is why CMA is urging its members to start planning their appearances at the ITC hearings, says Turnipseed. Meanwhile, CMA international experts, along with their counterparts at SOCMA, are surveying their members to see what products they consider to be "import sensitive" and should be exempted from Uruguay round tariff cuts. They also are asking chemical companies to identify products upon which they would like to have other countries make tariff concessions.

So far, the emphasis has been on the import sensitive items. CMA started out by sending its members a list of products—about 300 line items in the HTSs—that had been considered import sensitive in the previous two GATT rounds of multilateral trade talks (the Kennedy round and the Tokyo round). The replies, along with those from SOCMA members, will be distilled and a new list sent back out for final member review.

This list probably will contain about 120 HTS line items. Based on preliminary work, it's likely that most of the products that chemical companies will consider to be import sensitive will fall in chapter 29 (organic chemicals), although chapters 32 (dyes) and 28 (inorganics) will have more than their share of candidates.

The "turnaround" time for this final review, says Turnipseed, will be fast. It will have to be, because the combined results of the CMA and SOCMA surveys probably will become the basis for OCITA's testimony at the ITC hearings in Washington in April.

But neither CMA nor OCITA can do the job that individual chemical companies can at the ITC hearings, or at the subsequent hearings that will be held by USTR. "It's not enough to just say that a product is import sensitive," says Turnipseed. "You have to back up the words with sound economic and marketing data." And only the companies, he says, can provide that data.

ITC staffers will have to condense all the information they receive from their hearings and written submissions into a report for USTR. In addition, USTR's trade policy staff committee will hold its own hearings, with every article in the tariff schedules up for grabs.

USTR's hearings probably will start soon after ITC's end. They will have to, because Carla Hills, the new U.S. Trade Representative, and her Uruguay round crew won't have much time to formulate their battle plan for the actual negotiations on tariff cuts. At the midterm GATT meeting held in Montreal in December to assess progress in the Uruguay round (C&EN, Jan. 9, page 17), GATT ministers agreed to start "substantive" negotiations on tariffs no later than July 1, 1989. Before that, countries must exchange tariff and trade data and establish detailed negotiating procedures.

At the Montreal meeting, GATT ministers also set a target for overall tariff reductions in the Uruguay round "at least as ambitious as that achieved in the Tokyo round." Tariff cuts in the Tokyo round averaged 30 to 35%.

Although the Montreal meeting produced important agreements in 11 of the 15 Uruguay round negotiating groups, including tariffs, these agreements were put on hold until April so that negotiators could try to reach a consensus in all 15 negotiating areas. The four stumbling blocks are agriculture, safeguards (temporary import restrictions), textiles, and intellectual property rights. By far, the most important—and perhaps the most difficult—to resolve is agriculture, with intellectual property not far behind.

There's a chance that one or more of the 11 agreements already reached could disintegrate before April. And there's also little doubt that there can be no success in any area without success in agriculture and intellectual property. But if GATT history has taught the U.S. chemical industry anything, it is that trade negotiators seem to be able to agree on a package of tariff cuts, even when they can't agree on anything else.

That's why, as far as tariffs are concerned, the industry's trade policy leaders want U.S. chemical companies to give government officials their best shot whenever and wherever they get the chance. □

Venture Capitalists Cautious About High-Temperature Superconductors

Many see eventual payback as too far off and uncertain and consider it premature to invest in field still in research, instead of development, phase

Ann M. Thayer,
C&EN Northeast News Bureau

While scientists continue to ask questions about superconductivity that begin with what, how, and why, entrepreneurs and venture capitalists are starting to ask "How much?" and "How soon?" And, although it's been only two years since the discovery of high-temperature superconductors, questions like these are already forming the center of discussions about the commercialization of applications.

At a recent conference in San Francisco sponsored by the Superconductor Applications Association, nearly half the sessions were devoted to discussions on superconductor manufacturing and applications, markets, and venture capital for startup companies.

Despite apparent enthusiasm for high-temperature superconductors, it is generally expected to take from five to 15 years, and maybe longer, for commercial products to be realized from superconducting materials. These estimates are based on analyses of the state of technology and analogies with other high-technology industries such as semiconductors, computers, and biotechnology. From these models, developing technologies are expected to grow along predictable, evolutionary paths from initial discovery through R&D to applications. Although the superconductor development path is generally perceived to be the same, some analysts are more optimistic about its rate of evolution because of a high level of excitement and interest in the field.

At least two generations of high-temperature superconductor companies are emerging—companies that have dealt in existing low-temperature superconductor applications and are now exploring high-temperature superconductors, and new ventures that have been created specifically to exploit the newer high-temperature materials. The latter case was portrayed in the results of a recent study—"What do venture capitalists think about superconductivity?"—presented at the conference by a panel from Coopers & Lybrand, an accounting and management consulting firm. Based on interviews with nearly 100 of the most active venture capitalists, the study provides an interesting perspective on commercializing superconductivity through small startup companies: Although most venture capitalists seem to find superconductivity an exciting technical frontier, very few have actually invested.

Venture capitalists look for high returns on their investment (at least 10 times), usually within a period of five to seven years. With the outlook for commercializing high-temperature superconductors further off than that, many venture capitalists are unwilling to invest in such long-term projects. Robert H. Stavers of Coopers & Lybrand indicates that the majority of venture capitalists sees the eventual payback as too far off and uncertain, and considers it premature to invest in a field still in the research, rather than development, stage. Many have taken the time to review business plans but find them lacking in a product/market focus.

CY SAN FRANCISCO

C&EN staff photo

Stavers: tremendous opportunity

A sizable minority, about 27%, says Stavers, is very optimistic, seeing superconductivity as a tremendous opportunity for investment. Of this 27%, only 15 "pioneer" venture capitalists, with strong beliefs in the technology and strong stomachs to face long-term, high-risk investments, actually have invested. Not unexpectedly, the study shows, these venture capitalists previously had experience in investments of this type. The pioneer investors interviewed have funded a total of seven ventures in which, by pooling their money, they were able to reduce the risk to individuals. The average, first-round investment was $3.2 million per venture, explains Stavers, which is not high relative to other ventures such as semiconductor companies, which averaged about $4.9 million per venture in seed capital.

The desire to obtain an early position has caused some companies to spring up even before a business plan, product design, or management team has been coordinated. In doing so, venture capitalists acted quickly to attract top scientists and gain patent or technology transfer rights from major universities and research centers. American Superconductor Corp. of Cambridge, Mass., which has associations with Massachusetts Institute of Technology, and Conductus Inc. of Palo Alto, Calif., which was established with a group from Stanford University and the University of California, Berkeley, are examples. As often happens under these circumstances, a member of the venture capital group will direct the company until the staff is assembled. John Shoch of Asset Management Co., the lead venture capital firm behind the funding of Conductus, initially acted as its president.

Shoch, along with many other venture capitalists, sees similarities between superconductor and biotechnology startup companies, most basically the presence of a dramatic new technology coupled with strong science advisers and strong, experienced investors. He suggests that small companies can be, and have been, the appropriate place for the development of certain technologies. Small companies have the focus, incentive to succeed, and agility to respond quickly to new developments—features that will be necessities in the rapidly changing field of high-temperature superconductors.

Because of the limited number of venture capitalists willing to invest in high-temperature superconductors, the formation of venture capital-backed companies now appears to be slowing down, indicates Shoch. Some of the largest venture capital firms may also choose to stop investing if they decide that they already have succeeded in recruiting the top scientists and wish to concentrate their efforts internally on existing companies. In addition, venture capitalists are expected to avoid past mistakes, when budding industries were flooded with too many new companies. The new companies also are starting to develop substantial corporate backing, says Shoch. For example, Hewlett-Packard Co. has a cooperative research agreement with Conductus and has taken a 15% equity investment in the superconductor company's second round of funding.

Only a few major corporations, such as AT&T, IBM, and Du Pont, have significant R&D efforts in high-temperature superconductors, and small companies are looking to corporations as partners rather than competitors. Alliances with large companies are expected to attract further venture capital and possibly government contracts. Hal Hurwitz of Coopers & Lybrand suggests that unlike venture capitalists, whose primary goal is return on investment, corporations can be motivated to invest because of their interest in new product developments and potential technological and manufacturing improvements, in addition to financial goals.

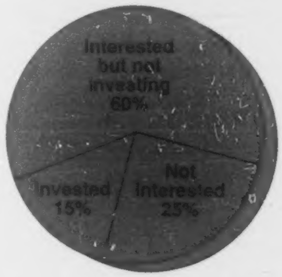
The capital needed to continue funding product development in the new superconductor companies is estimated to be on the order of $6 million to $9 million per venture. In addition to corporate capital, money might be available from remaining holdouts in the group of venture capitalists that gave rise to the pioneer investors. An even larger pool of venture capitalists, who appear interested but have hesitated to invest, might be looked to for second-round financing when the technology has advanced and there is less risk, but smaller returns.

Most early investors seem to expect that prototype products can be manufactured in two to five years, with eventual returns to be on a "grand-slam" scale, commensurate with the risk involved, of 50 to 100 times the original investment. Whereas extensive commercialization may be far in the future, observers predict that small-scale electronics applications, probably with correspondingly small commercial impact, will soon appear in niche markets. For example, John H. Vanston, president of the consulting firm Technology Futures Inc., Austin, Tex., says that firm has identified more than 100 applications for superconducting materials, one quarter of which could be available in the next three years. Vanston also suggests that the driving force behind these early developments is based not so much on the temperature profile of the materials, but rather on their electronic properties.

Sheridan Tatsuno, program manager of Dun & Bradstreet's Dataquest, analyzes high-technology markets. Whereas some observers are making guesses of hundreds of millions to a billion dollars for the size of potential markets in the next decade, Tatsuno hesitates to do this since the markets are just that—potential. "It takes about seven to 10 years for a technology to start gaining acceptance and a market, and about 15 years for it to really pick up," he says. "Right now there is nothing on which to base a guess since the market for high-temperature superconductors is zero." He believes, though, that small-scale electronics applications will appear in the market on a limited basis by 1991 or 1992 and expects these to come primarily from Japanese companies. This is because, he says, "it is the Japanese who will go for extremely simple devices first, whereas the U.S. traditionally looks to design more sophisticated, more difficult-to-produce applications."

Possible applications in the short term include items such as superconducting quantum interference devices (SQUID), sensors (magnetic, infrared, and microwave), switches, optical devices, and interconnects. Most of these devices are based on thin-film technologies, which are the most rapidly progressing area of superconducting materials processing. By taking advantage of the high-frequency characteristics of such materials, Conductus plans

Few venture capitalists invest in superconductivity



Total = 98 venture capitalists

Source: Coopers & Lybrand

to manufacture superconducting thin films for electronics applications.

Products based on bulk materials, such as wires and cables, will take much longer to develop because of the numerous limitations in the properties and processing of high-temperature superconducting materials. However, the goal of American Superconductor Corp. is to produce superconducting wires in the near future. The company has obtained rights to Argonne National Laboratory's wire technology (C&EN, Oct. 17, 1988, page 5) and a license for a wire manufacturing process recently patented by MIT (C&EN, Dec. 5, 1988, page 5). Interference with the patent is expected from the Japanese, who have submitted patents on similar processes.

Investors are particularly concerned about patent issues—the overall distribution and types of patents and how commercialization and competition in superconductor markets will be affected. Currently, the University of Houston, University of Alabama, University of Tokyo, IBM, AT&T, and Naval Research Laboratory are in competition for the patent on the yttrium-barium-copper oxide superconductor (1-2-3 material) in what looks to be a complicated dispute. However, a frequently expressed opinion is that it is very unlikely that a single patent stranglehold on the technology will come about or that patents on the materials themselves will be of overriding importance. Instead, it is expected that high-temperature superconductor commercialization will involve a variety of patents covering materials, processing, and products, and that there will be a great deal of cross-licensing of these patented technologies. To many, the most crucial concerns are centered around patents in international markets, and specifically, the role played by the Japanese.

The Japanese have been filing patents aggressively, with an estimated 2000 applications in Japan and nearly 25% of the 700 applications filed in the U.S. Of all patent applications filed in the U.S., about a third are foreign, and 10 to 15% may be put on the "patent fast track" implemented by former President Reagan. ◻

Chemical associations eye suspension policies

For any trade association, contemplating suspension of a member company is a serious matter. Recently, the West German Chemical Industry Association (Verband der Chemischen Industrie, VCI) suspended Imhausen Chemie, the company charged with supplying a chemical weapons plant in Libya (C&EN, Feb. 6, page 4).

According to Helmut Sihler, president and chief executive officer of VCI member company Henkel Corp. and current president of the association, the action against Imhausen Chemie was taken for several reasons. One reason was to lessen possible adverse consequences—including negative public opinion and possible tighter legislation or regulation—that could affect the chemical industry and the science of chemistry.

Another major reason was "verband hygiene." In effect, Sihler said, the association could not allow the impression that it condoned such actions if they appeared to have taken place.

VCI had tried talking with Imhausen Chemie, a maker of fine chemical intermediates for pharmaceuticals and agrochemicals, Sihler said, but he noted that the company had given the association only vague, unsatisfactory answers. Sihler did not specify what these answers were. The association then felt compelled to suspend the company, which had—as with many West German companies—been affiliated with VCI since it was formed shortly after World War II.

Sihler: possible adverse consequences

Thus far, few if any other chemical industry associations have had to consider taking similar action. However, for many reasons these days, they are now beginning at least to think about the possibility.

For example, on a different issue, the Chemical Manufacturers Association, in Washington, D.C., has written into its bylaws special provisions for suspension or expulsion, to accompany its new "Responsible Care" program, launched last year. Covering health, safety, and environmental quality, the program aims to improve the performance of the industry by developing management codes based on the best practices throughout the industry, explains Jon C. Holtzman, vice president of communications for CMA.

Under the bylaw provisions, he says, companies must agree to participate in the program for membership in CMA. They agree to act in good faith to implement what is needed to abide by the codes of the program. "Should a company sign on and then be so cynical as not to do anything, we would talk with them," he says. "If there was then no change on their part, we would disassociate with them."

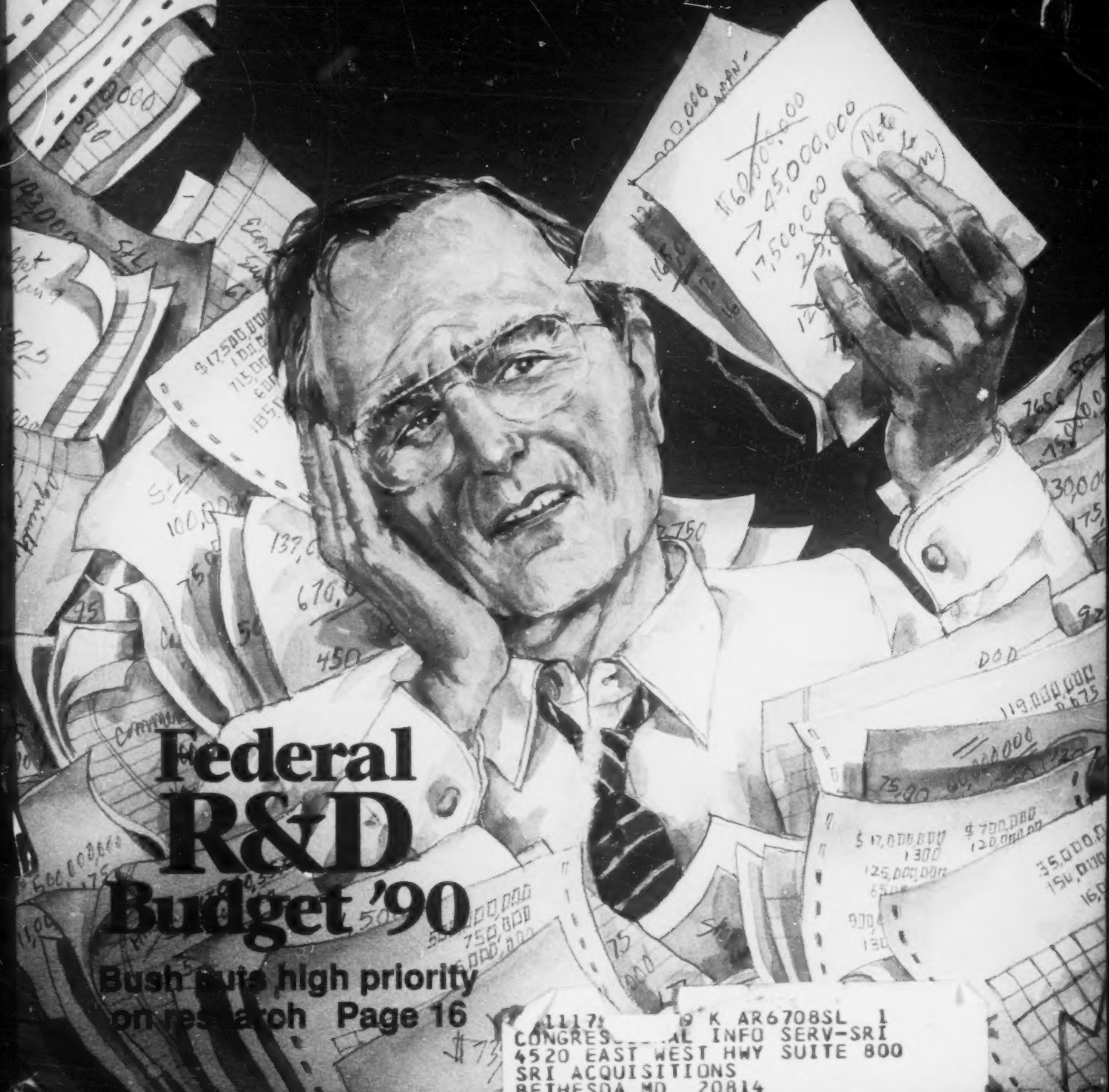
The process would follow established lines: It would take a two thirds vote of the board of directors to lead to a suspension or expulsion because a member broke the bylaws or engaged in conduct prejudicial to the association—conduct contrary to the safe manufacture of chemicals and to acting in the public interest. "Our bylaws would not only permit us, but would require us to look at these things," Holtzman says.

One difficulty is that membership in an industry organization is voluntary. Points out John Cox, director general of the Chemical Industries Association (CIA), in London, the U.K. counterpart to CMA and VCI, "There is no obligation on chemical companies to become members. The association takes steps to encourage more companies to take up

Chemical industry earnings continued to rise strongly in fourth quarter Page 9

FEBRUARY 20, 1989

CHEMICAL & ENGINEERING NEWS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Federal R&D Budget '90

Bush puts high priority on research Page 16

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FEBRUARY 20, 1989

News of the Week

- **Union Carbide to pay Indian government $470 million as compensation to victims of 1984 methyl isocyanate disaster in Bhopal.** Page 4
- **Institute of Medicine report urges universities to take steps to strengthen ethical standards in research.** Page 5
- **In latest restructuring effort, W. R. Grace & Co. is exploring partial sale of its noncore businesses.** Page 6
- **President Bush reaffirms his intentions for top role for White House science adviser.** Page 6

Letters 2

Concentrates

Business 7
Government 15
Science/Technology 21

The Departments

People 31
Awards 32
Newscripts 48

Business

Earnings of major U.S. chemical companies climbed an average 56% in the fourth quarter, capping a year of strong growth. **Page 9**

Plastics will keep their edge in competing with other materials in spite of price rises last year. **Page 14**

Science

Highly efficient route to synthesis of complex alkaloids features polycyclization reaction. **Page 22**

Technology

Scientists tackle challenge of putting superconductors to work, make most progress in thin-films area. **Page 24**

Books

"Collapse of an Industry" by John L. Campbell takes a look at how the American political process has worked against the nuclear power industry. **Page 29**

Government

President Bush's fiscal 1990 federal budget favors increased funding for science, particularly basic research, big science projects, and science education. Page 16

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LETTERS

Chemist sets example

SIR: Congratulations to Edward J. Poziomek, who received the Maryland Chemist of the Year Award for 1988. I feel that Poziomek is a dedicated chemist who has done a lot for the image of chemistry.

I recall an experience in grade school when he visited our classroom and spent several hours doing dramatic, thought-provoking experiments and answering questions about science. I feel that his lecture is responsible for my career commitment to chemistry. Following his example, I have taken just an hour out of the year to demonstrate an example of chemistry to my son's grade school class.

Thank you, Dr. Poziomek, and all scientists who are willing to devote a few hours to educating or communicating information about science to others. Certainly, ACS and National Chemistry Day or Week give everyone the opportunity to participate. Education has been proven the answer to long-range problems, time and again—all it requires is a little input from all of us.

G. Herold
Baltimore

Chemical industry for society

SIR: I was amazed to read a letter by Philip Sadtler (C&EN, Nov. 21, 1988, page 3) about a Rotary Club speech. This year, for the first time in our local schools, we the Rotarians of Ambarnath and members of Marathi Vidnyan Parishad, observed Chemistry Day on Dec. 3, 1988—the anniversary of the Bhopal tragedy.

We had six lectures and some demonstrations. The program was attended by more than 500 final year high school students and teachers. The speakers included a research manager of a local chemical unit (the undersigned), a professor of chemical engineering, a government technical officer in charge of pesticides, a consultant on environment, a director of a chemical unit, and a retired American research worker of Du Pont Co., who was visiting here. The theme of all the talks was "Chemical Industry for the Society." The speakers, one by one, explained to the young boys and girls how the chemical industry helps mankind to meet the primary needs of food, clothing, shelter, energy, and physical and mental well-being and clean environment through adoption of better technologies. The American scientist (also a Rotarian), who spoke, was so pleased with the 100-minute program that he said when he went back, he would start something like this in his hometown.

Such programs are important because good students have started shying away from chemistry and chemical engineering.

V. M. Vaidya
President, Rotary Club of
Ambarnath, India

Polyethylene glycol

SIR: Anatomical features of wood help explain why "the efficiency of polyethylene glycol treatment is widely debated" (C&EN, Nov. 14, 1988, page 10). Roughly 25% of the volume of wood (density 0.4 g per cc) is that of the cell walls or wood substance—a complex network of lignin and polysaccharides. The remaining 75% is void volume. One hundred grams of wood, fully waterlogged, contain about 215 g of sorbed water, of which 35 g are adsorbed in the wood substance. The aim of treatment is to replace most of this adsorbed water with an equivalent volume of polyethylene glycol. Access to cell walls is by diffusion in the remaining 180 g of "free water." However, this water is confined in closed cells 10 to 40 μm in diameter and 1 to 3 mm in length. Diffusion of polyethylene glycol between cells occurs through membranes perforated with submicroscopic pores of varying effectiveness.

Here, then, is the reason for the long times required to treat large sections of waterlogged wood. At the cell walls,

Laboratory accident information wanted

Science teachers who have personal knowledge of a serious laboratory accident are invited to contribute their story for a manual on safety. It will be geared toward the middle school through junior college teacher, and will be a compilation of accidents or near misses that have actually taken place in the laboratory. Strict confidentiality will be observed. Send contributions to Clair G. Wood, Eastern Maine Vocational Technical Institute, 354 Hogan Rd., Bangor, Me. 04401.

Chemical Earnings Close 1988 With Continued Strong Growth

William J. Storck,
C&EN Northeast News Bureau

Gains in earnings among U.S. chemical companies in the fourth quarter capped a year of strong growth in the industry. Earnings for 29 major chemical companies increased an average of 56% in the quarter, and earnings at oil, diversified, and drug companies that produce chemicals also improved.

Although this is the slowest earnings growth rate for the year (the same group of companies registered growth of 66% in the first quarter, 70% in the second, and 65% in the third), it still portends well for the immediate future.

Sales for the 29 companies also increased, rising 16% for the quarter from the year-earlier level.

Higher prices and production contributed to the improvement during the period. Government figures show that prices for chemicals and allied products in the fourth quarter were up about 11% over the same period in 1987. And output for the final three-month period last year rose about 9% over fourth-quarter 1987.

Much of the strength for the quarter was in basic chemicals, as it has been in the previous periods. In fact, that strength in commodities is hurting some of the smaller specialty-oriented companies, whose profit margins are being squeezed by rapidly rising costs for feedstocks such as ethylene and benzene. These firms are finding it hard to pass

Chemical industry leaders for the fourth quarter . . .

Sales			
Rank 1988		$ Millions	Rank 1987
1	Dow Chemical	$4299.0	1
2	Union Carbide	2139.0	3
3	Monsanto	1881.0	2
4	W. R. Grace	1651.7	4
5	American Cyanamid	1103.1	5
6	Quantum Chemical	806.7	7
7	Hercules	749.0	6
8	Arco Chemical	745.0	11
9	Air Products	640.6	8
10	Olin	623.0	12

Earnings[a]		
	$ Millions	Rank 1987
Dow Chemical	$635.0	1
Union Carbide	219.0	2
Arco Chemical	134.0	3
Quantum Chemical	119.3	4
American Cyanamid	62.8	4
Air Products	61.1	6
Ethyl	58.9	8
W. R. Grace	55.5	7
Georgia Gulf	54.4	12
B. F. Goodrich	52.5	13

Profitability		
	Earnings as % of sales	Rank 1987
Georgia Gulf	19.2%	1
Arco Chemical	18.0	3
Vista Chemical	16.1	2
Quantum Chemical	14.8	11
Dow Chemical	14.8	7
Aristech	13.5	12
International Flavors	12.8	4
Ethyl	11.4	5
Loctite	10.9	10
Betz Laboratories	10.7	6
Nalco Chemical	10.7	8

. . . and for full-year 1988

Sales			
Rank 1988		$ Millions	Rank 1987
1	Dow Chemical	$16,682.0	1
2	Union Carbide	8,324.0	3
3	Monsanto	8,293.0	2
4	W. R. Grace	5,786.1	4
5	American Cyanamid	4,592.0	5
6	Quantum Chemical	2,921.9	7
7	Hercules	2,802.0	6
8	Arco Chemical	2,700.0	11
9	Rohm & Haas	2,535.0	8
10	Air Products	2,489.6	9

Earnings[a]		
	$ Millions	Rank 1987
Dow Chemical	$2410.0	1
Union Carbide	720.0	3
Monsanto	591.0	2
Arco Chemical	494.0	5
Quantum Chemical	382.7	6
American Cyanamid	305.6	4
Ethyl	231.0	9
Rohm & Haas	230.1	8
B. F. Goodrich	220.9	14
Air Products	219.5	10

Profitability		
	Earnings as % of sales	Rank 1987
Arco Chemical	18.3%	2
Georgia Gulf	18.3	3
Vista Chemical	16.1	7
Aristech	15.4	14
International Flavors	15.3	1
Dow Chemical	14.4	10
Quantum Chemical	13.1	5
Ethyl	11.5	4
Betz Laboratories	10.8	6
Nalco Chemical	10.7	9

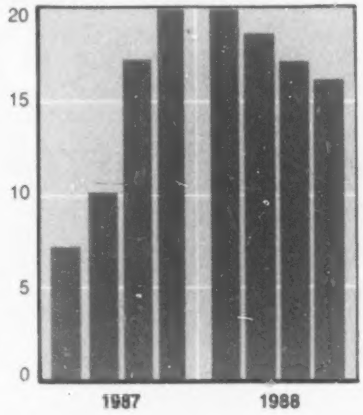
Note: for 30 companies listed on page 11. a After taxes.

Chemical industry 1988 fourth-quarter results

- **Sales rose 16%**
- **Earnings soared 56%**
- **Profit margins at 9.2%**
- **Production gained 9.3%**
- **Prices increased 11%**

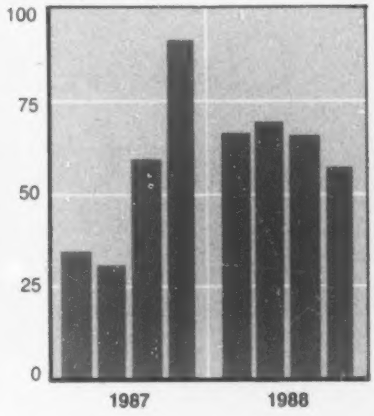
Sales

% change from year-earlier quarter



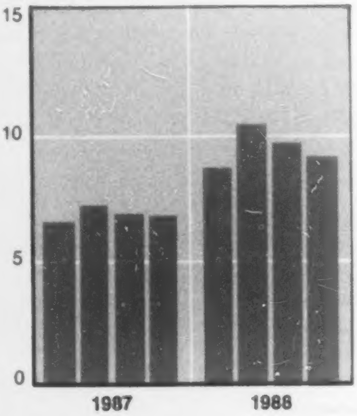
Earnings

% change from year-earlier quarter



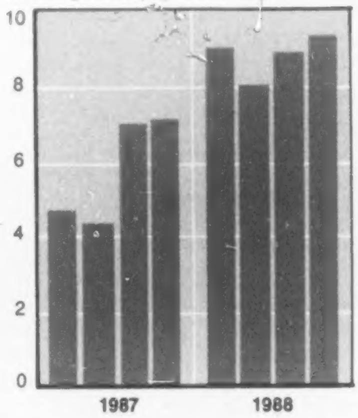
Profit margins

After-tax earnings as % of sales



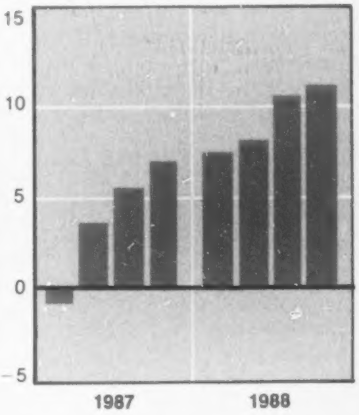
Production

% change from year-earlier quarter



Prices

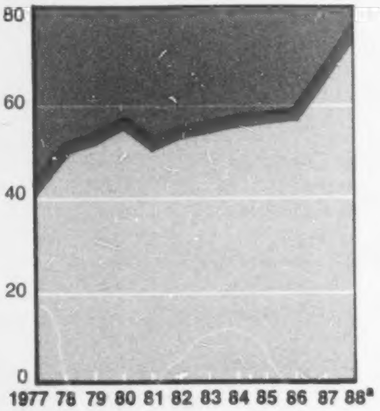
% change from year-earlier quarter



Sales in 1988 increased 19% and earnings climbed 61%, yielding a profit margin of 9.6%

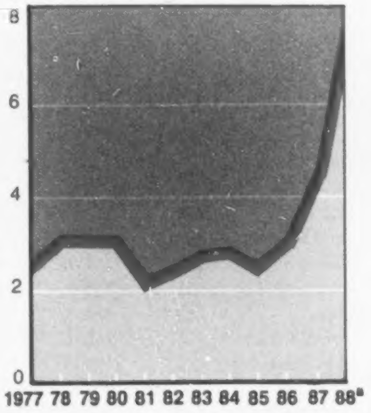
Annual sales

$ Billions



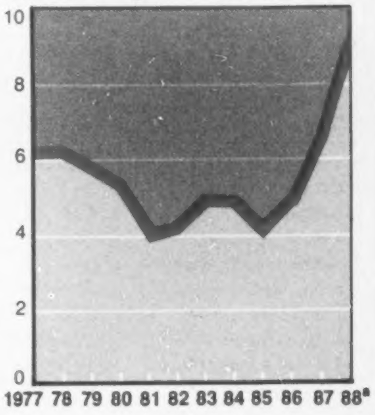
Annual earnings

$ Billions



Annual profit margins

After-tax earnings as % of sales



Note: All sales, earnings, and profit margin data are based on combined results of 30 companies on page 11. a C&EN estimates.

Fourth-quarter profits for 29 major chemical companies climbed 56% to $1.82 billion

	FOURTH-QUARTER 1988						FULL-YEAR 1988					
	Sales	Earnings[a]	Change from 1987		Profit margin[b]		Sales	Earnings[a]	Change from 1987		Profit margin[b]	
	($ millions)		Sales	Earnings	1988	1987	($ millions)		Sales	Earnings	1988	1987
Air Products[c]	$ 640.6	$ 61.1	9%	10%	9.5%	9.4%	$ 2,489.6	$ 219.5	14%	24%	8.8%	8.1%
American Cyanamid[c]	1,103.1	62.8	8	4	5.7	5.9	4,592.0	305.6	10	16	6.7	6.3
Arco Chemical[c]	745.0	134.9	47	116	18.0	12.2	2,700.0	494.0	38	92	18.3	13.2
Aristech	258.5	34.9	7	63	13.5	8.8	1,065.2	164.5	16	136	15.4	7.6
Betz Laboratories	115.1	12.4	15	23	10.7	10.1	447.6	48.4	16	19	10.8	10.5
Cabot Corp.[c]	480.1	22.8	24	40	4.7	4.2	1,769.9	61.8	28	7	3.5	4.2
Chemed	146.2	3.7	47	−22	2.5	4.7	500.6	20.6	28	1	4.1	5.2
Crompton & Knowles	85.6	4.2	66	28	4.9	6.3	289.8	16.8	45	40	5.8	6.0
Dow Chemical[c]	4,299.0	635.0	20	79	14.8	9.8	16,682.0	2410.0	25	94	14.4	9.3
Ethyl[c]	515.5	58.9	10	11	11.4	11.2	2,011.5	231.0	17	19	11.5	11.2
First Mississippi	96.3	6.1	12	95	6.3	3.6	331.5	25.3	2	19	7.6	6.5
H. B. Fuller	180.9	4.8	18	−34	2.7	4.8	685.0	21.1	15	−18	3.1	4.3
Georgia Gulf	283.6	54.4	40	55	19.2	17.4	1,060.6	193.6	50	111	18.3	13.0
B. F. Goodrich[c]	617.7	52.5	16	82	8.5	5.4	2,416.7	220.9	19	149	9.1	4.4
W. R. Grace[c]	1,651.7	55.5	27	4	3.4	4.1	5,786.1	192.1	28	35	3.3	3.1
Hercules[c]	749.0	23.4	10	−52	3.1	7.1	2,802.0	142.7	4	−32	5.1	7.8
International Flavors	181.3	23.2	1	9	12.8	11.9	839.5	128.7	13	20	15.3	14.3
International Minerals	241.0	15.0	14	2	6.2	6.9	1,054.1	87.9	nc	nc	8.3	4.2
Loctite	112.8	12.3	9	28	10.9	9.3	474.9	47.7	24	30	10.0	9.6
Lubrizol	na	na	na	na	na	5.2	na	na	na	na	na	8.0
Monsanto[c]	1,881.0	45.0	2	2	2.4	2.4	8,293.0	591.0	9	36	7.1	5.7
Nalco Chemical	262.0	28.1	14	27	10.7	9.6	994.2	106.0	18	32	10.7	9.5
Olin[c]	623.0	21.0	24	24	3.4	3.4	2,308.0	98.0	20	26	4.2	4.0
Pennwalt	263.5	13.2	23	104	5.0	3.0	1,023.6	48.3	21	46	4.7	3.9
Petrolite	74.2	2.1	−5	−42	2.9	4.7	301.4	13.0	8	−16	4.3	5.6
Quantum Chemical[c]	806.7	119.3	21	98	14.8	9.0	2,921.9	382.7	29	52	13.1	11.1
Rohm & Haas[c]	594.6	42.3	12	15	7.1	6.9	2,535.0	230.1	15	18	9.1	8.9
Union Carbide[c]	2,139.0	219.0	16	188	10.2	4.1	8,324.0	720.0	20	153	8.6	4.1
Vista Chemical	191.2	30.8	7	21	16.1	14.2	790.8	127.5	20	95	16.1	10.0
Witco[c]	384.0	20.4	4	57	5.3	3.5	1,585.9	71.6	11	13	4.5	4.4
Total 15 larger firms	**$17,229.9**	**$1572.9**	**16%**	**61%**	**9.1%**	**6.6%**	**$67,217.5**	**$6371.0**	**19%**	**62%**	**9.5%**	**7.0%**
Smaller 15 firms[d]	**$ 2,492.2**	**$ 245.3**	**17%**	**30%**	**9.8%**	**8.8%**	**$ 8,804.8**	**$ 961.4**	**21%**	**55%**	**10.9%**	**8.5%**
GRAND TOTAL[d]	**$19,722.1**	**$1818.2**	**16%**	**56%**	**9.2%**	**6.9%**	**$76,022.3**	**$7332.4**	**19%**	**61%**	**9.6%**	**7.2%**

a After-tax earnings from continuing operations excluding significant nonrecurring and extraordinary items. **b** After-tax earnings as a percentage of sales. **c** One of the 15 larger companies. **d** Totals for the quarter exclude Lubrizol. Totals for the full year exclude Lubrizol and International Minerals whose full-year figures are not comparable. **na** = not available. **nc** = not comparable.

along these increased costs to their customers.

For instance, at Vista Chemical, whose sales continued strong, president and chief executive officer John D. Burns said that the generally good results were affected negatively by higher costs for ethane and benzene, two of the company's principal feedstocks.

In spite of the profit squeeze at a few companies, the fundamentals of the industry remained strong. High demand for most chemical products, both in the U.S. and internationally, caused continued high operating rates at chemical plants. Government figures put capacity utilization for chemicals and allied products at about 90% in the fourth quarter, up from about 86% in the same period in 1987. And in some cases, especially among commodity plastics, according to industry sources, capacity use is much higher than this.

As a result, earnings growth for the industry remained robust in the quarter. For 29 of the 30 companies regularly surveyed by C&EN, earnings from continuing operations climbed 56% to a total of almost $1.82 billion on a sales rise of 16% to about $19.7 billion. Lubrizol's quarterly results have not been released.

Profit margins for the 29 firms rose to an average of 9.2% in the fourth quarter from just 6.9% in the year-earlier period.

The biggest gains were at the 15 larger firms in the group, earnings of which soared 61% to $1.57 billion in the fourth quarter. For the smaller 15 firms, earnings rose 30% to $245 million. But the sales gain for the smaller companies slightly outpaced that for the larger firms. Sales for the 15 larger companies rose 16% to $17.2 billion. For the smaller companies, sales increased 17% to $2.49 billion.

Profitability was higher for the smaller companies than for the larg-

Earnings increased at most oil, diversified companies

	FOURTH-QUARTER 1988						FULL-YEAR 1988					
	Sales	Earnings[a]	Change from 1987		Profit margin[b]		Sales	Earnings[a]	Change from 1987		Profit margin[b]	
	($ millions)		Sales	Earnings	1988	1987	($ millions)		Sales	Earnings	1988	1987
OIL AND GAS COMPANIES												
American Petrofina	$ 675.5	$ 32.9	1%	142%	4.9%	2.0%	$ 2,634.7	$ 132.9	6%	60%	5.0%	3.4%
Amoco	5,526.0	375.0	4	−1	6.8	7.1	21,157.0	2063.0	5	52	9.8	6.7
Ashland	2,100.0	96.0	5	20	4.6	4.0	8,208.0	239.7	11	29	2.9	2.5
Atlantic Richfield	4,548.0	391.0	−2	15	8.6	7.4	18,324.0	1583.0	8	29	8.6	7.2
Chevron	6,900.0	441.0	−7	63	6.4	3.7	28,900.0	1691.0	−1	70	5.9	3.4
Exxon	22,020.0	1380.0	1	−11	6.3	7.1	87,542.0	5250.0	5	8	6.0	5.8
Kerr-McGee	689.5	33.4	8	127	4.9	2.3	2,743.2	110.1	5	31	4.0	3.2
Mobil	13,886.0	448.0	−2	14	3.2	2.8	54,877.0	2038.0	7	67	3.7	2.4
Occidental Petroleum	5,284.0	52.0	20	126	1.0	0.5	19,417.0	358.0	14	95	1.8	1.1
Phillips Petroleum	2,860.0	135.0	−2	309	4.7	1.1	11,490.0	650.0	5	1757	5.7	0.3
Shell Oil	5,458.0	212.0	−7	−51	3.9	7.4	21,399.0	1204.0	1	−2	5.6	5.8
Sun Co.	2,720.0	93.0	4	−5	3.4	3.8	10,000.0	321.0	2	−12	3.2	3.7
Texaco	8,469.0	538.0	−10	55	6.4	3.7	35,138.0	2281.0	−1	78	6.5	3.6
Unocal	2,635.0	43.0	13	48	1.6	1.2	10,085.0	267.0	7	48	2.6	1.9
DIVERSIFIED MANUFACTURERS												
Allied-Signal	3,007.0	104.0	2	35	3.5	2.6	11,909.0	360.0	7	−8	3.0	3.5
Borden	1,983.3	93.9	10	15	4.7	4.5	7,243.5	31.9	11	−88	0.4	4.1
Du Pont	8,441.0	500.0	6	14	5.9	5.5	32,917.0	2190.0	8	23	6.7	5.9
Eastman Kodak	4,543.0	312.0	29	29	6.9	6.9	17,034.0	1397.0	28	19	8.2	8.9
Engelhard	695.1	19.2	−5	5	2.8	2.5	2,350.7	63.7	−5	8	2.7	2.4
FMC	882.1	36.0	3	555	4.1	0.6	3,286.9	129.2	5	34	3.9	3.1
Ferro Corp.	260.8	11.8	12	26	4.5	4.0	1,009.0	46.6	16	47	4.6	3.6
3M	2,579.0	272.0	9	26	10.5	9.1	10,581.0	1154.0	12	26	10.9	9.7
Morton-Thiokol	631.9	38.9	8	−1	6.2	6.7	2,461.1	159.7	14	15	6.5	6.4
PPG Industries	1,400.0	102.3	8	6	7.3	7.4	5,600.0	467.6	8	24	8.4	7.3
Vulcan Materials	267.4	25.1	9	−12	9.4	11.6	1,053.2	136.0	14	19	12.9	12.4
Tyler	167.7	0.8	7	−87	0.5	3.6	664.6	14.6	6	−38	2.2	3.8

a After-tax earnings from operations excluding significant nonrecurring and extraordinary items. b After-tax earnings as a percentage of sales.

er ones, although profit margins for the larger firms showed a stronger improvement. At the 15 larger companies, profit margins for the fourth quarter averaged 9.1%, up from 6.6% in the same period in 1987. For the smaller companies, the average profit margin was 9.8%, up from 8.8% in the year-earlier period. The average profit margin is calculated from the total sales and earnings for each group.

For the full year, the results were even more impressive than they were for the quarter. Earnings for 28 of the 30 companies surveyed rose 61% in 1988 to $7.33 billion on a sales increase of 19% to $76.0 billion. For the full-year totals, Lubrizol is not included, nor is International Minerals & Chemical (because of the spinoff of IMC Fertilizers into a separate company, data are not comparable).

Profit margins for the 28 companies averaged 9.6% in 1988, up considerably from 7.2% for 1987.

The full-year breakdown between the larger and smaller companies was similar, but not as drastic in difference, to that for the fourth quarter. Earnings for the 15 larger firms for all of 1988 rose 62% to $6.37 billion on a sales increase of 19% to $67.2 billion. The 13 smaller companies recorded earnings up 55% to $961 million on a sales increase of 21% to $8.80 billion.

As a result, the average profit margin for the larger companies increased to 9.5% in 1988 from 7.0% in 1987; that for the smaller companies rose to 10.9% last year from 8.5% in 1987.

The role of commodities as major contributors to earnings was confirmed by chemical results at oil companies during the quarter. Results from largely commodity-based chemical operations at eight major oil companies (Amoco, Atlantic Richfield, Chevron, Mobil, Occidental Petroleum, Shell, Texaco, and Unocal) show a 102% earnings gain for the quarter to $1.13 billion. For the year, earnings of these firms rose an average of 110% to $4.08 billion.

These results are inflated somewhat by Occidental's acquisition of Cain Chemical in May of 1988. Even without Occidental, however, the remaining seven companies registered a 76% gain for the quarter and an increase of 98% for the year.

Despite the good results, there are a few worrisome signs for the

Profits of most major pharmaceutical companies climbed

Earnings for major U.S. pharmaceutical firms rose markedly in the fourth quarter, registering an increase that outpaced that for the earlier quarters of 1988. Fourth-quarter earnings for 12 major drug companies surveyed by C&EN increased 33% from last year's fourth quarter to a total of almost $1.58 billion on a sales increase of just 9% to $11.7 billion.

For the full year, the earnings gain for the 12 firms was 20% to an aggregate $6.70 billion on a 12% sales gain to $45.8 billion.

As a result, profitability rose for the companies. The average profit margin for the 12 climbed to 13.5% in the fourth quarter from 11.2% in the same period in 1987. For the full year, the average profit margin was 14.6%, compared with an average 13.6% for the previous year.

Although most of the companies recorded fairly strong gains in the fourth quarter, earnings for two companies declined. Profits at financially troubled SmithKline Beckman dropped 20% to $113 million on a 7% sales rise to almost $1.28 billion. Henry Wendt, chairman and chief executive officer, said, "There is much work to be done to restore growth. But there were many positive developments in 1988, beginning with the creation of a unified worldwide pharmaceutical business." Wendt also cited gains in international pharmaceutical sales and "solid contributions to earnings" by other health care businesses.

But overall, SmithKline's ethical pharmaceutical sales declined, led by a fall in U.S. sales of its Tagamet antiulcer drug and Dyazide, a diuretic/antihypertensive.

A. H. Robins, the other company whose earnings fell and which has been left weakened by its Chapter 11 bankruptcy proceedings brought on by litigation over its Dalkon Shield intrauterine device, gave no reason for the decrease.

Chemical operations at drug companies showed mixed results. Eli Lilly had fourth-quarter sales of $798 million, an increase of 7% from the previous year. Higher sales of the herbicides Treflan and Sonalan were the primary contributors.

At Pfizer, fourth-quarter results showed a 9% decline in specialty chemical sales, a 6% drop in agriculture sales, and a 3% decline in materials science sales.

Merck, the remaining drug company with large chemical sales, did not comment about its results.

	FOURTH-QUARTER 1988						FULL-YEAR 1988					
	Sales	Earnings[a]	Change from 1987		Profit margin[b]		Sales	Earnings[a]	Change from 1987		Profit margin[b]	
	($ millions)		Sales	Earnings	1988	1987	($ millions)		Sales	Earnings	1988	1987
American Home Products	$1300.9	$238.6	7%	11%	18.3%	17.7%	$5500.5	$932.2	9%	10%	16.9%	16.8%
Bristol-Myers	1479.5	195.6	9	12	13.2	12.8	5972.5	829.0	11	17	13.9	13.1
Eli Lilly	1042.3	175.7	15	def	16.9	def	4069.7	761.0	12	85	18.7	11.3
Merck	1534.1	307.3	10	32	20.0	16.7	5939.5	1206.8	17	33	20.3	17.9
Pfizer	1368.2	141.6	7	4	10.3	10.7	5385.4	791.3	9	15	14.7	14.0
Rorer Group	325.2	26.9	16	20	8.3	8.0	1041.6	61.8	12	14	5.9	5.9
Schering-Plough	739.9	92.9	12	24	12.6	11.3	2969.4	389.8	10	23	13.1	11.7
SmithKline Beckman	1276.9	113.3	7	−20	8.9	11.8	4749.0	475.7	10	−17	10.0	13.2
Squibb	664.8	97.5	12	15	14.7	14.3	2585.8	425.5	20	19	16.5	16.6
A. H. Robins	241.0	32.1	3	−46	13.3	25.2	933.8	132.5	9	11	14.2	14.0
Upjohn	710.5	80.7	9	14	11.4	10.9	2746.2	353.4	9	16	12.9	12.1
Warner Lambert	997.9	77.5	11	17	7.8	7.4	3908.4	340.3	14	15	8.7	8.6

a After-tax earnings from operations excluding significant nonrecurring and extraordinary items. b After-tax earnings as a percentage of sales. def = deficit.

future. One of these is that the growth in earnings has been slowing for the past three quarters (albeit earnings are being compared with increasingly stronger quarters).

Government reports of seasonally adjusted shipments of chemicals and allied products show month-to-month declines in November and December. At the same time inventories have been building. Inventories also have been building for these two months for the narrower industrial chemicals category and month-to-month shipments for this category declined in December.

Also, shipments data for plastics published by the Society of the Plastics Industry show the same general pattern—a slowing in the latter part of the year.

It may, however, be too soon to tell. The shipments and inventory data may simply be a result of year-end inventory adjustments by downstream customers. This, at least, is what companies seem to be saying.

Georgia Gulf's James R. Kuse, chairman and chief executive officer, says, "Overall supply and demand for the products we produce were in close balance for most of the year. As a result, nearly all of our plants operated at or near capacity with very little accumulation of inventories at either plant or customer levels. There was, however, some general leveling of demand from earlier peak periods during the latter part of the fourth quarter."

At Aristech, chairman Thomas Marshall says that polypropylene is not expected to be so strong a performer as in 1988. As the year ended, there was some compression in margins. This was a result of a severe reduction in purchases by China coupled with capacity increases at four U.S. producers. Marshall adds that raw material prices also began to escalate in the fourth quarter.

In spite of what at this time seem to be only small worries, most companies are predicting a good 1989.

B. F. Goodrich says that polyvinyl chloride sales slowed in the fourth quarter because of seasonal factors, but early indications are that shipments of the plastic will continue to grow in 1989.

Dow president and chief executive officer Frank P. Popoff states, "While 1988 was an outstanding year for the company, Dow management is clearly focused on continued profit growth in 1989 and beyond."

At Du Pont, the largest U.S. chemical producer, chairman Richard E. Heckert comments, "We look forward to further earnings improvement in 1989. The economic outlook for 1989 calls for moderate growth and potential stability for crude oil prices. In this environment we expect to maintain the momentum built by our businesses in recent years, further improving shareholder value." □

Plastics expected to retain competitive edge

Plastics will hold the edge in the ever-increasing competition among materials despite rapid price rises last year. With additional capacity coming to ease current demand pressures, plastics will continue to improve their position. Cost/performance improvement through continuing innovation will give plastics a bigger share of markets such as packaging and automotive at the expense of metals, glass, and paper.

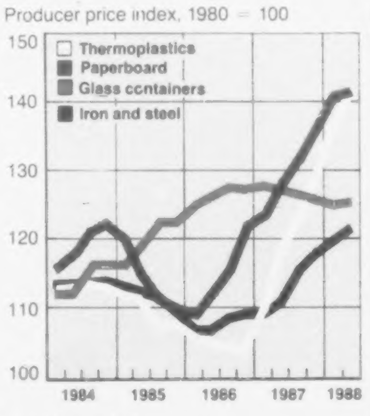
Better performance remains the key to demand for plastics growing significantly faster than demand for other materials. Cost is very important, but higher-priced plastics offer so much better performance that they will continue to replace other materials. These were some of the major conclusions of the Chemical Marketing Research Association meeting held in Houston earlier this month on the outlook for competing materials and technologies.

The prices of some materials competing with plastics also have increased markedly, notes William C. Kuhlke, a specialist in studies of volume plastics and vice president of De Witt & Co., a Houston-based consulting firm. By the middle of 1988, the price of paperboard, for example, increased about the same as that of thermoplastics, even though prices of thermoplastics such as low-density polyethylene had risen 34% and general-purpose polystyrene had skyrocketed 106% from lows in 1986. There are a few temporary shifts to other materials from plastics because of higher prices—for instance, ductile iron is replacing polyvinyl chloride in large-diameter pipe.

To have a lasting major shift in materials, however, two things must happen, Kuhlke says. First, the new material must have properties equal to or superior to those of existing materials, offer a dramatic performance improvement such as resistance to corrosion or to shattering, or eliminate manufacturing steps. Second, the price differential must be large, 10% or more, to justify converting to a new material. The differential also must be expected to continue for an extended period.

For instance, the higher cost of raw materials for polyethylene terephthalate (PET) in 1988 adversely affected its growth in soft-drink bottles, according to Fred W. Voigt Jr., an Eastman Chemical Products market research associate. For the first time, demand for PET in bottles in the second half of a year was lower than in the first half. But PET use will continue to grow in the soft-drink container industry for several reasons, he says, one of which is the tight supply of aluminum. In addition, PET producers have a capital cost advantage over aluminum producers. For instance, for the same amount of capacity for producing soft-drink containers, aluminum producers would have to invest about double the capital—for smelter capacity—compared with what PET producers would have to invest for capacity starting with ethylene and *p*-xylene.

Thermoplastic, paperboard prices have jumped



Source: DeWitt & Co.

In the automotive industry, innovation will cause further shifts to the use of plastics. For example, rapid growth in applications is expected for a new glass-fiber-reinforced polypropylene composite developed by Exxon Chemical Americas, says Richard M. Burkhart, the company's venture manager for structural thermoplastic composites. These composites are finding increased acceptance in the automotive industry because of cost savings in tooling, labor, and materials, and because they provide greater design flexibility.

North American automakers consumed between 25 million and 30 million lb of fabricated composites last year, according to Burkhart. With growth at 15 to 20% per year, demand for these items in both existing and new applications is projected to exceed 200 million lb by the year 2000.

Plastics also compete with other plastics. Performance can make nylon film a better material than polyethylene film for the carrier web used in fabricating sheet-molding compound, a matrix of a resin-filler paste and glass fibers, according to Olinda W. Rush, Allied-Signal's product manager for composite fabrication materials. The higher cost of nylon film is partially offset by the use of 1-mil film instead of the 2-mil film required if polyethylene is used. Less scrap and breakage result, further reducing the cost disadvantage of nylon film in making sheet-molding compound.

Bruce Greek

Bush Budget Proposal Calls For Increases in R&D Funding

Proposal favors budget increases for basic research, big science projects such as the Superconducting Super Collider, science education

David J. Hanson and Janice R. Long,
C&EN Washington

As promised, President George Bush unveiled his plan for "building a better America" on Feb. 9. His first budget plan is generally more than kind to science, as was Bush in his first State of the Union message to Congress. In the budget and the address, Bush said he favors increased funding for basic research, supports big science projects such as the Superconducting Super Collider, and wants to improve science education.

With his emphasis on R&D, particularly basic research, as a means of advancing American competitiveness and encouraging economic growth, Bush sounded uncannily like his predecessor, Ronald Reagan. Bush suggests fiscal 1990 funding levels for R&D that are close to what Reagan proposed on Jan. 9 (C&EN, Jan. 16, page 6). And where the numbers aren't identical, they are, in many cases, higher rather than lower.

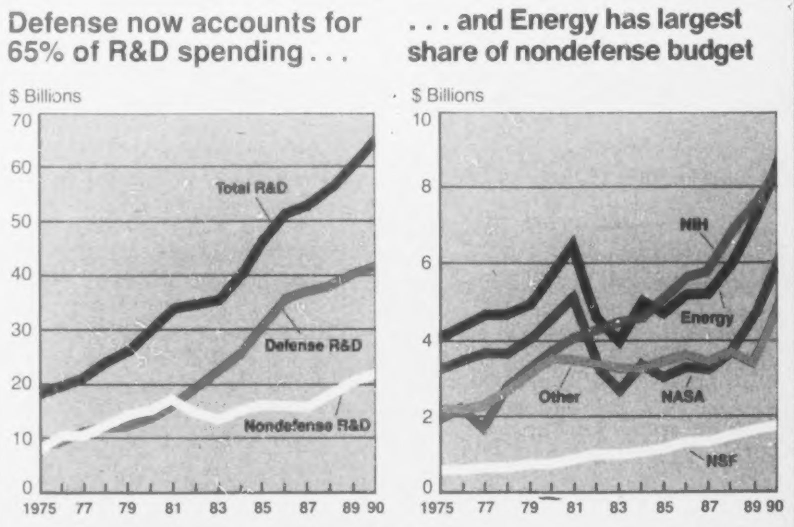
For example, Bush told Congress, "I propose almost $2.2 billion for the National Science Foundation to promote basic research and keep us on track to double its budget by 1993." Reagan proposed a fiscal 1990 NSF funding level of $2.15 billion, which can easily be rounded off to the same amount as in Bush's proposal.

According to the Bush budget document, this 14% increase will allow NSF to support the engineering research centers, the advanced scientific computing centers, and the 11 interdisciplinary science and technology centers announced in 1988, plus thousands of individual researchers at universities and colleges, all of which NSF was already planning to do under the Reagan budget proposal.

NSF clearly falls into a category—"Advancing Priorities for Growth and Competitiveness"—that is one of five "key priority" categories that the Bush Administration has targeted for funding increases in the coming fiscal year. Competitiveness is to be enhanced by increasing federal investments in R&D even beyond the current strong level.

Also falling into that category, and thus candidates for budget increases, are Department of Energy general science programs, funding of which was slated to rise almost 30% in the Reagan budget proposal. And DOE's Superconducting Super Collider is singled out as a "critical part of this Administration's initiative to strengthen the position of the nation as a world leader in science and technology. . . . It will produce discoveries, innovations, and spinoffs that could touch profoundly every American." Thus, Bush is seeking budget authority of $250 million in 1990, again identical to Reagan's proposal, for the federal share of construction funding for the collider.

But he parts company with Reagan in seeking $710 million, an increase of 274% over 1989 funding, for DOE's clean coal technology program. Reagan had asked for $325 million for the program. The increased funding reflects Bush's commitment "to ending the long debate on acid rain. The time for action has come," say the budget documents. In addition to honoring the U.S. pledge to Canada to devote $2.5 billion in federal funds over five years for the clean coal tech-



Note: Outlays. **Source:** Office of Management & Budget nology program, the Bush Administration intends to ask Congress to establish an acid rain program that will obtain significant reductions in sulfur dioxide and nitrous oxides within a specified period.

To provide real reductions as quickly and efficiently as possible, the Administration says its legislation will provide market-based incentives for early deployment of innovative emission reduction techniques and will remove disincentives to the use of clean-burning fuels like natural gas, methanol, and ethanol.

In his State of the Union message Bush told Congress, "I request funding for the National Aeronautics & Space Administration and a strong space program: an increase of almost $2.4 billion over the current fiscal year. We must have a manned space station, a vigorous, safe space shuttle program, and more commercial development in space. The space program should always go 'full throttle up.' That's not just our ambition, it's our destiny." Reagan requested a $2.2 billion increase to $13.1 billion for NASA.

In the Reagan proposal, NASA's R&D budget was up 22%, with much of the increase slated for the controversial space station, up 125% to $2 billion. Bush calls "Space Station Freedom" the keystone of the U.S. space policy. He also believes in a balanced and flexible space transportation program and would supply enough funds to the space shuttle program for nine flights in fiscal 1990.

Bush has also committed himself to improved biomedical research, and his budget recommendations declare that basic research in medicine is a public good that would be underfunded without the federal investment. He sees the need for advanced training of top quality, highly skilled biomedical researchers.

Here Bush again parts company with Reagan, proposing an overall 3.6% increase for biomedical R&D (excluding research on acquired immune deficiency syndrome) and, within that, a 6.6% increase for basic biomedical research. Also excluding AIDS research, Reagan had asked for a 5% cut in the National Institutes of Health's R&D budget

TOTAL FEDERAL R&D BUDGET PROPOSAL

Obligations for R&D are up 7% in 1990. . .

	Obligations			Outlays		
$ Millions	1990[a]	1989[a]	1988[b]	1990[a]	1989[a]	1988[b]
Defense[c]	$41,518	$38,879	$37,063	$39,437	$37,306	$35,417
Health & Human Services	8,375	7,892	7,161	8,094	7,345	6,862
NASA	6,870	5,688	4,339	6,152	4,741	3,832
Energy	5,378	5,307	5,081	5,501	5,259	4,989
NSF	1,881	1,864	1,533	1,756	1,634	1,494
Agriculture	1,044	1,048	1,014	1,043	1,020	972
Interior	387	432	415	391	432	415
EPA	421	386	347	405	364	340
Transportation	332	329	304	384	391	321
Veterans Affairs	205	238	217	201	208	199
Commerce	201	441	561	278	449	413
Agency for International Development	177	184	193	218	222	234
All other	556	563	554	560	527	529
TOTAL	$67,345	$63,051	$58,773	$64,418	$59,896	$56,017

Note: Excludes R&D facilities funding. a Reagan Administration estimate. b Actual. c Includes military-related R&D programs of the departments of Defense and Energy. Source: Office of Management & Budget

. . . and basic research commitments are up 6% . . .

	Obligations			Outlays		
$ Millions	1990[a]	1989[a]	1988[b]	1990[a]	1989[a]	1988[b]
Health & Human Services	$4,756	$4,417	$4086	$4,621	$4,152	$3914
NSF	1,754	1,553	1433	1,638	1,527	1399
NASA	1,462	1,438	1113	1,407	1,318	1019
Energy	1,389	1,303	1183	1,402	1,304	1171
Defense[c]	929	939	873	954	936	835
Agriculture	511	490	477	499	479	457
Interior	128	147	128	131	148	129
Smithsonian Institution	87	79	75	85	78	73
EPA	76	44	27	73	40	28
Commerce	28	30	31	29	31	28
Veterans Affairs	16	19	17	16	18	16
All other	24	28	27	25	26	28
TOTAL	$11,160	$10,467	$9468	$10,880	$10,057	$9098

a Reagan Administration estimate. b Actual. c Includes military-related R&D programs of the departments of Defense and Energy. Source: Office of Management & Budget

. . . but R&D facilities obligations are down 1%

	Obligations			Outlays		
$ Millions	1990[a]	1989[a]	1988[b]	1990[a]	1989[a]	1988[b]
Energy	$1089	$ 904	$ 921	$ 968	$ 888	$ 886
NASA	589	561	428	511	484	399
Defense	520	604	450	500	466	422
NSF	86	60	57	80	65	57
Agriculture	58	109	135	136	113	78
Health & Human Services	22	146	22	52	72	33
All other	68	69	80	69	63	57
TOTAL	$2432	$2453	$2093	$2316	$2151	$1932

a Reagan Administration estimate. b Actual. Source: Office of Management & Budget

HOW THE AGENCIES FARE

Health research gains from AIDS funding

$ Millions	1990^a	1989^a	1988^b	% change 1989–90
National Institutes	$6978.0	$6564.4	$6088.6	6%
Cancer	1646.1	1571.5	1469.3	5
Heart, Lung & Blood	1082.5	1045.9	965.5	3
General Medical Sciences	781.3	682.3	638.0	15
Diabetes & Digestive & Kidney Diseases	582.6	559.7	534.7	4
Neurological & Communicative Disorders & Stroke	502.0	480.2	459.0	5
Allergy & Infectious Diseases	842.7	743.6	640.3	13
Child Health & Human Development	444.2	425.6	396.6	4
Eye	239.5	231.3	224.6	4
Environmental Health Sciences	230.8	223.7	215.7	3
Aging	230.5	222.8	194.7	3
Arthritis & Musculoskeletal & Skin Diseases	166.6	160.0	147.7	5
Dental Research	135.8	130.8	126.3	4
Deafness	91.4	87.0	75.7	5
Other	434.4	515.0	523.2	−16
TOTAL	$7412.4	$7079.4	$6611.8	5%

Note: Obligations for AIDS research have been added to each individual institute. a Reagan Administration estimate. b Actual. Sources: National Institutes of Health, Office of Management & Budget

NSF's total budget is up 14% . . .

$ Millions	1990^a	1989^a	1988^b	% change 1989–90
Mathematical and physical sciences	$ 553.5	$ 503.3	$ 472.0	10%
Geosciences	341.3	310.3	290.7	10
Biological, behavioral, and social sciences	314.5	281.5	265.1	12
Engineering	211.2	187.3	172.1	13
Computer and information science and engineering	191.2	152.1	123.9	26
Science and engineering education	190.0	171.0	139.2	11
Antarctic program	156.0	131.0	124.8	19
Program development and management	104.0	91.7	84.5	13
Scientific, technological, and international affairs	67.3	58.3	50.1	15
Science and technology research centers	20.0	0.3	0	566
TOTAL	$2149.0	$1886.8	$1722.4	14%

Note: Obligations. a Reagan Administration estimate. b Actual. Source: National Science Foundation

. . . funding for the sciences is up 10% . . .

$ Millions	1990^a	1989^a	1988^b	% change 1989–90
Ocean sciences	$ 152.9	$ 146.2	$134.8	5%
Materials research	135.2	115.0	110.6	18
Physics	130.0	122.6	117.9	6
Atmospheric sciences	109.4	98.7	96.2	11
Chemistry	103.4	96.6	94.0	7
Astronomical sciences	94.0	89.5	85.8	5
Mathematical sciences	76.0	65.9	63.8	15
Biotic systems, resources	76.0	62.9	58.7	21
Earth sciences	65.2	54.2	51.3	20
Cellular biosciences	60.6	55.6	53.9	9
Molecular biosciences	51.4	46.6	44.5	10
Behavioral, neural sciences	46.3	44.8	43.6	8
Social, economic sciences	33.2	30.9	30.1	7
TOTAL	$1135.6	$1029.5	$986.3	10%

Note: Obligations. a Reagan Administration estimate. b Actual. Source: National Science Foundation

. . . and chemical programs are up 12%

$ Millions	1990^a	1989^a	1988^b	% change 1989–90
Materials research	$135.2	$115.0	$110.6	18%
Project support	74.4	68.6	66.4	8
Laboratories and groups	36.2	34.3	33.6	6
National facilities	24.6	12.1	10.6	103
Chemistry	103.4	96.7	94.0	7
Physical	29.8	28.5	28.1	5
Organic and macromolecular	25.0	23.8	22.6	5
Inorganic, bioinorganic, and organometallic	16.6	16.0	14.2	4
Analytical and surface	13.5	12.7	12.0	6
Special projects	9.6	7.3	8.7	31
Instrumentation	8.9	8.4	8.4	6
Chemical and thermal systems engineering	36.0	33.3	31.7	8
Fluid, particulate, and hydraulic systems	9.9	9.3	8.9	6
Interfacial, transport, and separation processes	9.9	8.7	7.8	14
Thermal systems	8.8	8.3	8.2	6
Chemical reaction processes	7.4	7.0	6.8	6
Biochemistry	14.5	13.5	13.2	7
Cellular biochemistry	12.7	11.9	11.5	7
TOTAL	$301.6	$270.4	$261.0	12%

Note: Obligations. a Reagan Administration estimate. b Actual. Source: National Science Foundation

and only a 3% rise in its basic research budget.

Under the Bush budget proposal, total spending for AIDS research by all federal agencies would be boosted to $1.6 billion, a rise of $313 million from fiscal 1989. To accelerate advances in medical research, Bush also hopes to see new partnerships formed between industry and the federal research establishment. He will allow Reagan's proposal for $100 million for the mapping of the human genome to stand, hoping that this initiative will promote American competitiveness and leadership in the health industries.

Bush's call for a freeze on real growth in defense spending probably means that Department of Defense R&D programs, which were slated to rise 9% in the Reagan budget proposal, would be held to the rate of inflation, which is forecast at about 4% in 1990. The freeze would apply for only one year, according to Bush. After that, he says, increases above inflation will be required.

The Reagan DOD R&D budget once again proposed a major increase (54%) for the Strategic Defense Initiative (C&EN, Feb. 13, page 8). Bush has pledged that SDI will continue, but the $1.9 billion increase to $5.6 billion for 1990 may

Air, interdisciplinary R&D lead EPA rise

$ Millions	1990^a	1989^a	1988^b	% change 1989–90
Air	$ 84.2	$ 69.1	$ 65.5	22%
Interdisciplinary	77.7	39.4	28.1	97
Superfund/underground tanks	69.3	73.8	54.6	−6
Hazardous waste	42.3	45.4	43.8	−7
Energy/acid rain	38.2	54.9	55.3	−30
Toxic substances	28.0	28.0	26.4	0
Water quality	26.3	24.2	24.4	9
Drinking water	23.3	21.5	22.4	8
Pesticides	14.3	13.5	12.7	6
Management & support	13.7	13.1	11.0	5
Radiation	4.2	3.6	2.7	17
TOTAL	$421.5	$386.5	$346.9	9%

Note: Obligations. a Reagan Administration estimate. b Actual. Source: Environmental Protection Agency

Cooperative research still down at USDA

$ Millions	1990^a	1989^a	1988^b	% change 1989–90
Agricultural Research Service	$ 604.6	$ 584.3	$ 551.9	3%
Cooperative State Research Service	295.4	348.5	352.0	−15
Forest Service research	133.8	137.9	132.5	−3
National Agricultural Library	14.9	13.3	12.2	12
TOTAL	$1048.7	$1084.0	$1048.6	−3%

Note: Obligations. a Reagan Administration estimate. b Actual. Source: Department of Agriculture

Growth slows for DOD R&D

$ Millions	1990^a	1989^a	1988^b	% change 1989–90
Conduct of R&D	$41,024	$37,543	$37,027	9%
Tactical programs	14,942	13,169	11,998	13
Advanced technology development	7,840	5,897	5,356	33
Strategic programs	5,628	6,481	7,227	−13
Intelligence and communications	4,697	4,499	4,885	4
Program management and support	4,624	4,019	4,251	15
Technology base	3,293	3,478	3,310	−5
R&D facilities	520	604	450	−14
TOTAL	$41,544	$38,147	$37,477	9%

Note: Obligations. a Reagan Administration estimate. b Actual. Source: Office of Management & Budget

Basic research paces rise in DOE R&D budget

$ Millions	1990^a	1989^a	1988^b	% change 1989–90
ENERGY R&D	$3663.3	$3552.3	$3352.7	3%
Basic research	2027.0	1737.5	1619.4	17
General science	1166.5	918.8	904.3	27
High-energy physics	616.2	559.4	559.1	10
Nuclear physics	299.5	260.9	245.2	15
Superconducting Super Collider	250.0	98.6	0	154
Basic energy sciences	590.0	549.3	557.7	7
Materials sciences	202.5	180.5	170.3	12
Chemical sciences	149.9	132.9	127.2	13
Other	237.6	235.9	260.2	1
Biological, environmental research	271.5	268.3	257.4	1
Nuclear	352.9	354.9	347.0	−1
Magnetic fusion	349.3	351.1	331.2	−1
Clean coal technology	325.0	190.0	196.9	71
Fossil	163.6	380.6	327.0	−57
Supporting research activities	20.5	127.8	155.8	−6
Environmental safety, health	124.6	91.0	71.1	37
Solar and other renewables	112.5	156.8	148.1	−28
Conservation	87.9	162.6	156.2	−46
DEFENSE R&D	2614.9	2535.8	2511.9	3
Weapons R&D, testing	1962.9	1905.8	1904.9	3
Naval reactors development	652.0	630.0	607.0	3
TOTAL	$6278.2	$6088.1	$5864.6	3%

Note: Obligations. a Reagan Administration estimate. b Actual. Sources: Department of Energy, Office of Management & Budget

Space station represents 33% of NASA R&D

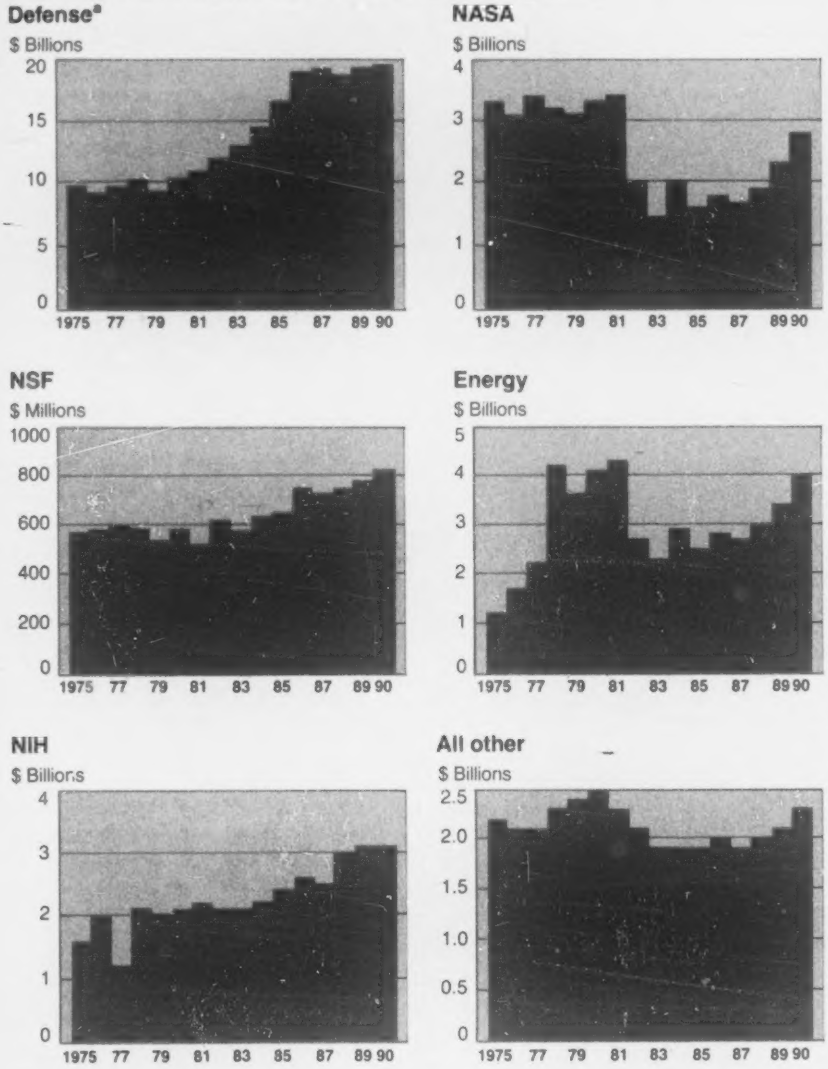
$ Millions	1990^a	1989^a	1988^b	% change 1989–90
Conduct of R&D	$5677.5	$4663.8	$3334.5	22%
Space station	1992.7	887.1	489.5	146
Physics and astronomy	886.5	765.0	585.8	16
Space capability development	641.1	848.2	598.6	−24
Space applications	580.8	724.9	577.5	−20
Aeronautical research	459.9	412.9	324.1	11
Planetary exploration	397.9	422.5	347.5	−6
Space research & technology	336.0	325.9	206.9	3
Life sciences	121.9	80.0	67.6	52
Transatmospheric vehicle	124.1	69.3	51.3	79
Commercial programs	60.2	84.9	48.9	−29
University space program	33.3	—	—	—
Safety & quality assurance	23.3	23.7	17.1	−2
Tracking & data acquisition	19.8	19.4	17.7	2
R&D facilities	341.8	275.1	213.2	24
TOTAL	$6019.3	$4938.9	$3547.7	22%

Note: Obligations. a Reagan Administration estimate. b Actual. Source: Office of Management & Budget

be in jeopardy. The basic research portion of the defense budget was slated for a 5% cut, to just under $3.2 billion. When President Bush made his proposal this month, defense spending was slated to rise only $9.1 billion compared with the Reagan rise of $15.4 billion, but a DOD spokesman says that specific changes to the budget have not yet been made. The department has 60 days in which to decide how it will meet Bush's target numbers. In Bush's outline for the 1990 budget, he gives no guidance on how defense R&D will be handled.

If one assumes that Bush's call for a freeze on domestic spending—no increases allowed for inflation—applies to all the programs not specifically targeted for increases, then a freeze might actually translate into good news for a few R&D funding agencies. The Department of Agriculture, for example, might welcome a freeze in its R&D budget, which was slated for a 3% cut by Reagan, as might the Department of Interior, whose R&D budget would be cut 10%, and the Department of Commerce, whose R&D budget was slated for a 55% cut.

However, it is bad news for the Environmental Protection Agency, whose R&D budget as a whole was up 9% under Reagan. Bush has made



Since 1975, defense R&D has doubled and NSF, Energy, and NIH R&D have also scored sizable gains

Note: Outlays in constant 1975 dollars. **a** Includes Department of Defense and Department of Energy military-related programs. **Source:** Office of Management & Budget

a major commitment to environmental matters, but how that will be reflected in the agency's R&D budget remains to be seen. Overall, Reagan's EPA proposal will probably stand, although agency budget staffers say there could be some rearrangement of R&D priorities once the Bush people assume their positions. One of the largest increases would come in air quality research, where EPA would get about $14.1 million for assessing the global impact of climate change. This is a 440% increase over fiscal 1989 funding levels.

In other areas, Bush's budget proposal makes good on a number of promises he made during his Presidential campaign. For instance, in the education area, Bush is calling for establishment of a national science scholars program. Under the program, four-year scholarships of up to $10,000 per year would be provided for students majoring in the sciences, mathematics, or engineering. One student would be nominated for the program by each member and delegate in the House of Representatives, one by each Senator, and 30 by the President, for a total of 570 scholars each year. Annual competitions would be held to select nominees for the scholarships. The program would be funded at a level of $5 million in 1990, rising to $20 million per year by the fourth year.

Finally, the Bush budget contains some proposals that would affect the chemical industry. Again Bush follows Reagan's lead in calling for a permanent extension of the 20% research and experimentation tax credit and establishment of a liberalized base for calculating the amount of the credit. However, under the Bush plan, deductions for research expenditures would be reduced by the full amount, rather than the current 50%, of the credit taken.

In addition, Bush is advocating adoption of a permanent and "more beneficial" formula for allocating research and experimentation expenditures between domestic and foreign income. Bush's proposed rules would permit a 67% expense allocation to U.S. source income. The remaining portion would be allocated on the basis of gross sales or gross income, with no limitation on use of the gross income method, according to the budget documents.

However, Bush is also going along with the plan, first introduced in the Reagan budget, to generate revenues for the federal government from the phase-in of the international agreement reducing the use of chlorofluorocarbons to preserve the ozone layer. The Administration intends to charge the market value for the production rights remaining under the agreement.

As always, what the President proposes must be agreed to by Congress. So although Bush's budget proposals, particularly in the R&D area, are very similar, if not identical, to Reagan's, the chances of the numbers being the same when fiscal year 1990 begins are slim to zero. That's especially true this year, because Bush's budget proposal, although calling for increased funding in many areas, doesn't specify what other areas are to be cut to fund those increases and still meet the mandatory deficit reduction targets. He left that question open to negotiation. □

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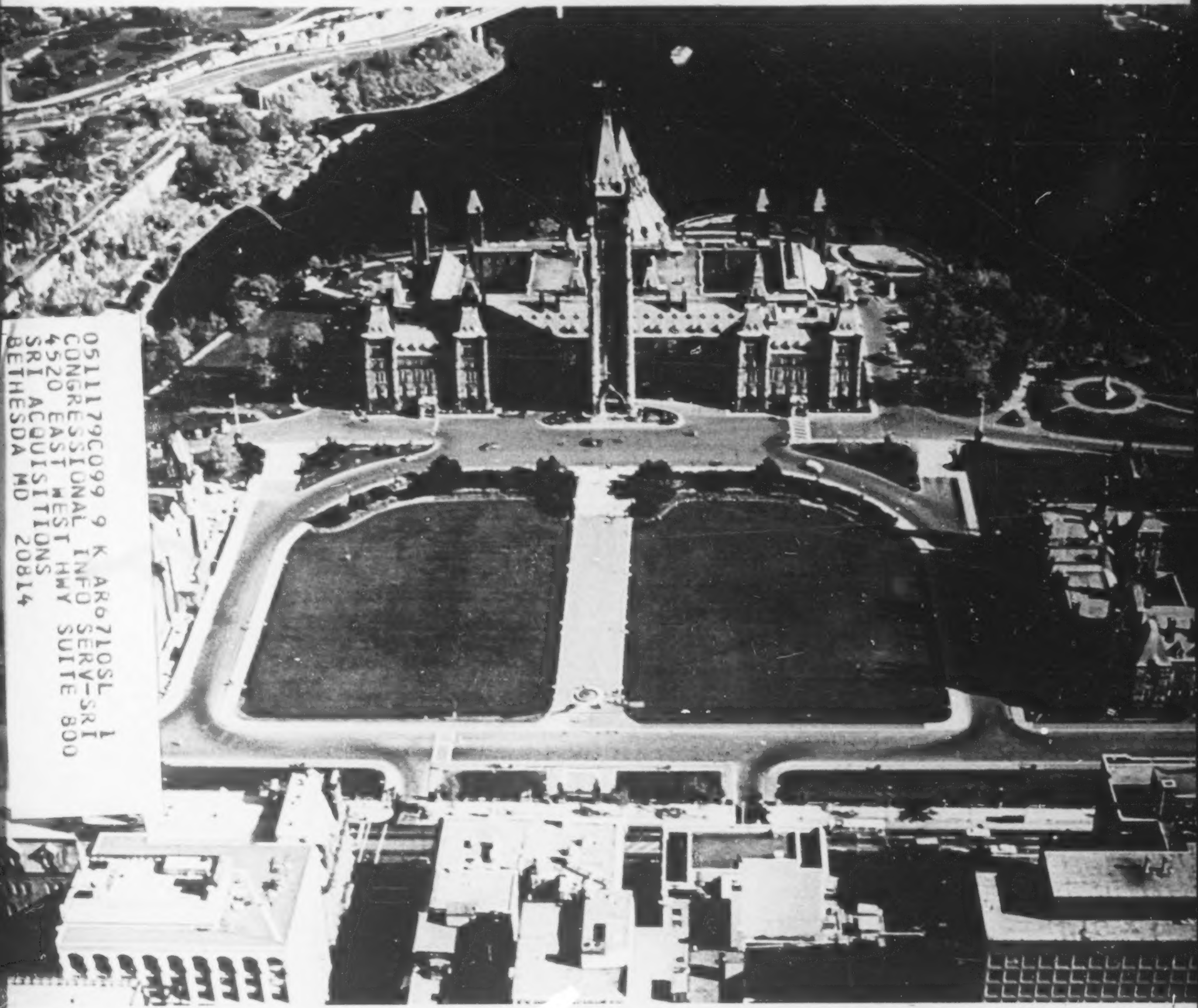
Expedition uncovers threat to Arctic ozone Page 29

MARCH 6, 1989

CHEMICAL & ENGINEERING NEWS



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Science in Canada

Struggling for a policy Page 7

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CHEMICAL & ENGINEERING NEWS

MARCH 6, 1989

News of the Week

- **Four former Du Pont employees are arrested for alleged $10 million extortion threat relating to theft of trade secrets on spandex fiber production.** Page 4
- **Three chemical engineers are convicted of illegally storing, treating, and disposing of hazardous waste at Aberdeen Proving Ground in Maryland.** Page 4
- **Catalytic antibody that catalyzes hydrolysis at a specific site in a peptide is developed by scientists at Research Institute of Scripps Clinic, La Jolla, Calif.** Page 5
- **Morton Thiokol announces intent to divide current firm into two new companies, Thiokol Corp. and Morton International.** Page 6
- **NRC review of literature on links between diet and disease leads to recommendations for changes in the American diet.** Page 6

Cover: Canada's Parliament Buildings in Ottawa. Photo courtesy of Canadian Embassy, Washington, D.C.

Letters 2
Editor's Page 3
Concentrates
Business 15
Government 23
Science/Technology 27
The Departments
ACS News 35
Awards 38
Meetings 54
Newscripts 56

Business

Delegates from Middle East petrochemical industry confer on making such downstream products as polymers and fibers. **Page 20**

Government

Plant inspection protocol aims to check for diversion of commercial chemicals to chemical arms use. **Page 24**

Export controls on sensitive technologies debated by federal agencies including CIA and Defense Department. **Page 25**

Technology

Federal clearance for wider tests of its genetically engineered microbial pesticide InCide is sought by Crop Genetics International. **Page 28**

Science

Very little seems to stand in way of Arctic ozone hole is conclusion of researchers returning from first comprehensive probe of Arctic stratosphere. **Page 29**

Deterioration of global environment is accelerating, says report by Worldwatch Institute. **Page 32**

First compound whose molecules are tied in cloverleaf knots is made by French chemists. **Page 33**

Perkin Medal

Frederick Karol is recognized for his outstanding achievements in applied chemistry. **Page 34**

News Focus

The existence of a Canadian science and technology policy continues to be debated, but the government is giving more attention to research and technology. **Page 7**

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LETTERS

Biodegradation of PCBs

SIR: I read with interest your article on biodegradation of PCBs (C&EN, Nov. 21, 1988, page 5). However, it was incorrect to report that "heavily substituted polychlorinated biphenyls (PCBs) . . . have now for the first time been proven to be biodegradable."

I conclusively demonstrated biodegradation of heavily chlorinated biphenyls in 1985 using a mixture called Aroclor 1254 (54% chlorine by weight with between 4 and 7 chlorines per molecule) [*Enzyme Microb. Technol.*, **7**, 194 (1985)]. These experiments showed that *Phanerochaete chrysosporium* and other wood decay white-rot fungi are able to mineralize highly chlorinated PCBs. The degradation of [U-^{14}C]-Aroclor 1254 resulted in irreversible binding to the cells, release of water-soluble degradation products, release of $^{14}CO_2$, and disappearance of the gas chromatographic peaks.

David C. Eaton
Science & Technology Department
Hercules Research Center
Wilmington, Del.

Nuclear power

SIR: Mike McCormack (C&EN, Dec. 12, 1988, page 2) correctly identifies antinuclear activism as antienvironmentalism. Results of real antienvironmentalism are part of the scenery across Pennsylvania, West Virginia, eastern Kentucky, or southeast Ohio, where prime forestland has been, and continues to be, destroyed by coal mining, and in southwestern Indiana, where some of the country's most beautiful farmland is being turned into sterile piles of rubble and lifeless pools by strip mining. The antinuclear (actually antiscience) faddist assumes that stripping or undermining of farm and forestland is environmentally benign, naively believing that this despoiled land can be restored to pristine condition. Strip mine damage is forever: The land is ruined, toxic elements that had been tied up for geologic ages are released into groundwaters, and the burning coal releases these same toxic elements into air and land. Note also the loss of life in coal mining: more than 270,000 since 1900 in this country alone, plus innumerable cripplings from accidents and black lung. Of course, to the antinuclear activist this mass of deaths and cripplings is boringly commonplace, infinitely less titillating than any harmless reportable event at a nuclear power plant.

The problems of radioactive waste are political, not technical. We actually are more capable of handling radioactive waste than we are of protecting ourselves from fossil fuel wastes and from the effects of so-called renewable energy sources. Years of research and development have been well spent on methods for containing reactor waste. Years of controversy have also been wasted on where to dispose of nuclear waste. Scientific methodology—it is well known that answers fall out quickly once the right questions are asked—would replace, "How do we get rid of these radioactive wastes?" with "What can these wastes be used for?" After all, they contain a considerable quantity of usable low-grade energy. As added bonuses, by using this energy, we will always know where it is, and save further energy by avoiding expensive studies on ill-conceived disposal schemes.

Coal is a dangerously polluting energy source, and low-density energy sources—wind, water, wood, and refuse—cannot sustain an industrial society. We need vast amounts of power for running industry and households, and for purifying contaminated water and seawater for current needs and for reclamation of salinated lands. Because nuclear energy is the most controlled and controllable of all high-grade energy sources, it is the cleanest. High-density power sources other than nuclear will pollute the environment faster than it can be repaired.

In antinuclear propaganda, the following clichés are staples: "waste that will remain dangerously radioactive for N-thousand years"; "Why don't you tell us THE solution?"; and "Our descendants N-generations from now will bitterly curse us." The first cliché shows neither understanding of the physics of radioactive decay nor that radioactive elements follow rules of chemistry. The second cliché is expected from the nonscientist; from those with scientific training we should expect, "What are viable alternatives (if a real problem exists) among many proposed partial solu-

Continued on page 55

Correction

- Feb. 27, page 76: The Perrier Group's plant near Nîmes, France, produces a billion bottles a year of Perrier water, equivalent to more than 500 million L of water, not 500 L of water.

Canada Grapples with Its Science and Technology Policy

Debate persists between government and scientific community over whether country has a policy in place, but government is focusing more attention on research and technology and has taken some key steps

Earl V. Anderson, C&EN Northeast News Bureau

Following last November's convincing election victory, Canada's Prime Minister, Brian Mulroney, and the Progressive Conservatives are safely entrenched on Ottawa's Parliament Hill, preparing to lead Canada for another few years. One of the toughest jobs facing them when Parliament reconvenes late this month or in early April is coping with a budget deficit that, relatively speaking, is larger than that of the U.S.

Meanwhile, a new federal department—the Department of Industry, Science & Technology Canada (ISTC)—is being set up. A blend of the old Department of Regional Industrial Expansion and the Ministry of State (Science & Technology), ISTC has been taking shape ever since Mulroney announced its establishment in August 1987, although legally the department doesn't yet exist. Enabling legislation was sidetracked by last year's election but likely will be acted upon soon.

Just last month, as part of a major cabinet reshuffle, William C. Winegard became the new Minister of State (Science & Technology), replacing Frank Oberle, who had held the post during some trying times for Canadian science and technology policy. He will report to Harvie Andre, who will replace Robert R. de Cotret as head of the new ISTC.

All of these developments are certain to have an impact on Canada's science and technology policy. And scientists throughout Canada—in universities, industry, and government itself—are watching anxiously to see just what kind of an impact it will be.

That's because Canadian science policy is at a delicate and crucial crossroads. But then, Canada itself is at a crossroads. As the industrialized world becomes increasingly competitive and as more and more countries rely on advanced technology to maintain a sharp competitive edge, Canada has been undergoing an intensive self-examination.

Based on years of study after exhaustive study, it

National Research Council of Canada photo has become almost axiomatic now among leading Canadian industrialists, academics, and policymakers that Canada no longer can depend solely on its natural resource-based industries to carry the country into the high-tech 21st century. Most of them agree that Canada has to shake its old image as a "carrier of water and a hewer of wood." Canada's people—and their knowledge—now have become recognized as the crucial resource needed for the country's future economic growth.

Photo by Bill McCarthy

Prime Minister Mulroney (center) tours Canadian chemical plant

That means hitching Canada's wagon of international competitiveness to a horse of excellence in science and technology. In their first four years of office, Mulroney and the Progressive Conservatives have done a lot to pry such ideas out of the closet and into the public arena. But that does not solve the problem; it only underscores the fact that a problem exists.

Critics contend that there has been more rhetoric than action on science policy in Canada over the past few years. There is a degree of truth in that. But in many cases, the criticism reflects their belief that government simply has not pumped enough money into science and technology, or that the money could have been better spent on their projects instead of someone else's.

In fairness, the Mulroney government has provided more leadership and has given science and technology more attention than has been witnessed in Ottawa for many years. And there's little doubt that it has taken some significant steps to enhance science and technology in Canada.

But does that mean that Canada now has a definitive science policy solidly in place? It's not a facetious question. Many within the Canadian scientific community wonder about it openly. The answer depends upon whom you ask. Government officials involved in science and technology tell you emphatically that Canada, indeed, has a science policy. Not yet, say many individuals in the scientific community. It's still evolving.

The discord in Canada over science and technology policy is obvious. But whether such a policy does indeed exist is a tough question to answer. In part, it's tough because a lot depends upon what is meant by "policy." Geraldine A. Kenney-Wallace, a professor of chemistry and physics at the University of Toronto and, since late 1987, chairman of the Science Council of Canada, says that "policy is creating a climate in which things can get done." The Science Council is an arm's length advisory organization in the federal government.

For many years, she says, that climate hasn't been conducive to Canadian science and technology. But she thinks that over the past few years the climate has been changing substantially—and for the better. However, reverting to science-speak, Kenney-Wallace says, "We have not yet made the phase transition into a new era where science and technology are regarded as intrinsic parts of our economic and social fabric." Few Canadian scientists will disagree with that.

Nor does anyone doubt that what Mulroney's administration does during its present tenure in Ottawa will help decide whether Canada makes that phase transition. Canadian culture and cultural politics, unique among industrialized countries, will come into play. The seemingly endless debates about the relationships between science and government, between universities and industry, and between federal and provincial governments no doubt will continue. Different factions within Canada's scientific community will argue about the how and the how much. But more than ever before, there is a growing consensus that decision-making time has arrived.

Consensus building, in fact, has been a major part of Mulroney's science effort in his first tour of duty in Ottawa. And with very little dissent, there is a general consensus now that Canada will have to get its science and technology act together if it hopes to remain a strong competitor in the world marketplace.

For Canada, the bottom line is that it does not do enough research and development, not enough technology, not enough innovation. In short, Canada doesn't spend enough money on science and technology.

For this, government blames industry. Industry, in turn, blames government. They are both right.

By most measures, Canada does much less R&D than most of the industrialized countries that are—and will continue to be—its competitors. One popular measure is gross expenditures on R&D as a percentage of gross domestic product. According to the Organization for Economic Cooperation & Development (OECD), which compiles these data, Canada spends only 1.43%

of its gross domestic product on R&D. That puts Canada 10th in a list of 11 countries.

Audrey Doerr, director general of the federal research branch in ISTC's science sector, echoes what many Canadians believe in saying that such yardsticks may not be the best measure of science and technology in Canada. With its small population and an industry structured heavily in the natural resources, it's not unreasonable to expect Canada to rate low in such measurements.

Others say that measuring R&D spending as a percentage of gross domestic product says little, if anything, about how well research is converted into useful innovations by industry. They think that economic, political, and social factors play a far greater role in economic growth than simple percentage measurements of R&D spending.

Nevertheless, one reason for Canada's poor showing is that Canadian industry is a notoriously poor performer when it comes to science and technology. Looking at industrial spending alone, Canada again ranks 10th out of 11 countries, with its industry spending only 0.65% of industrial domestic product on R&D.

It's tempting to say that the government's dollar commitment is high compared with that of industry in Canada. Government, after all, does fund about 60% of all R&D in Canada, compared with roughly 40% by industry. But it's not high compared with other countries. On that score, Canada ranks dead last on the OECD list of 11 countries. Government spends only 0.58% of gross domestic product on R&D.

Fewer than 5% of all Canadian companies do the bulk of the industrial R&D in Canada. About three fourths of the companies do no R&D at all.

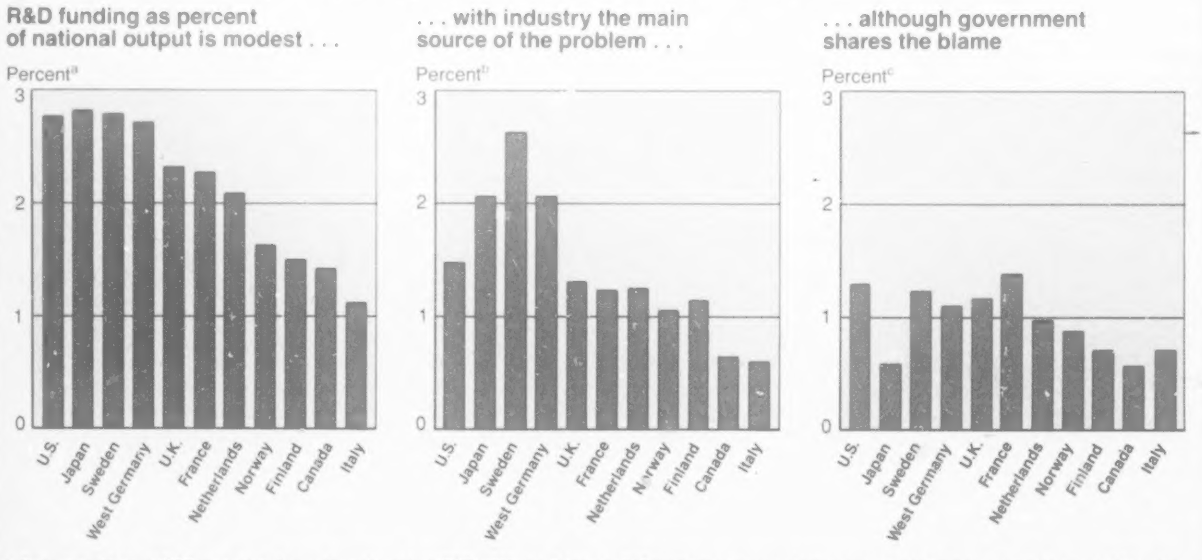
One explanation for this situation is that the Canadian domestic market is too small for companies to justify spending large amounts of money on R&D. This is especially true if the product line is not a good export candidate. Another is that Canada traditionally has tied its economic fortunes to its wealth of natural resources. And natural resource companies do not spend heavily on science and technology.

A more pervasive reason is that much of Canadian industry is owned by foreign companies, especially U.S. companies, which do the bulk of their R&D in their home countries and operate their Canadian subsidiaries as "branch plants." But Hugh C. Rowlinson, retired vice president for research and technology of C-I-L Inc., one of Canada's largest chemical companies, says this should be considered as positive, not negative as it's usually portrayed. It means, says Rowlinson, "that a great deal of research is available almost free."

Canadian industry, of course, has no one to blame but itself for the pittance it spends on R&D. But the government isn't blameless, either. The federal government directs a lopsided 62% of its total spending on science and technology to its own government laboratories. A miserly 16% or so goes to industry. And, although the government does support about 20% of industrial research in Canada (through grants, contracts, and tax measures), that is a small proportion compared with the U.S. and many other industrialized countries.

Regardless of where the blame lies, there's little argument that Canada will have to do a far better job on science and technology if it hopes to meet the high-tech competitive challenges that it faces. Former science minister Oberle says that government, indus-

Canada spends proportionately less on R&D than do most industrialized nations



a Gross expenditures on R&D as percent of gross domestic product (GDP); 1985 data. b Industry R&D spending as percent of domestic product by industry (industry's share of GDP); 1985 data, except Canada (1984). c Government R&D spending as percent of GDP; 1987 data, except Japan (1986). Source: Organization for Economic Cooperation & Development try, and the universities will have to work together to make it happen.

If it's going to happen at all, Canada's new ISTC will play a leading role. Billed as a "flagship" for the government's economic development efforts, the department's primary focus will be on improving Canadian industry's ability to compete in international markets. To do its job, ISTC will try to strengthen the country's science and technology base, from the most basic research to technology, and all the way through innovation to marketing. ISTC sends a signal loud and clear—the effort to improve science and technology in Canada will have a definite industry focus.

Former ISTC minister de Cotret says that the department is the one that "will speak to, for, and about industry, science, and technology in the government of Canada." And there's little doubt that what ISTC does will help determine the fate of science and technology in Canada.

However, neither de Cotret nor Oberle will be there to guide ISTC, because of the major cabinet reshuffling last month, in which Andre became ISTC minister and Winegard replaced Oberle as Minister of State (Science & Technology). Canada's scientific community is still trying to assess these changes. Initial reaction is favorable. Both know the science beat (Andre is a chemical engineer and Winegard is a metallurgical engineer). If nothing else, they should certainly increase the awareness level of science and technology within government. The still-unanswered question is how this increased awareness will be translated into action.

Some Canadian scientists, especially in academia, worry that the government's emphasis on R&D will drop because the science minister is a junior minister whereas the ISTC minister is a senior minister. Doerr says they are afraid that, by identifying science so closely with industry, basic R&D will suffer. Others dismiss that point of view, saying that what's really important is that science and technology now have their own "portfolio," or department.

Even more important, says Kenney-Wallace, is how much "clout" the new ISTC team will have. The answer to that has not yet been determined, but based on the cabinet assignments that Andre has received, the betting is that he will be able to hold the line against cutbacks in science and technology spending. He may not, however, be able to pry additional R&D funds out of government.

The new ISTC department is only one block in the foundation that Mulroney's conservative government has been laying under Canada's science policy since it roared into office in 1984 with the largest parliamentary majority in Canadian history. Although improving Canadian performance in R&D and technological innovation was part of their agenda from the start, the Conservatives started out poorly in the eyes of the scientific community. Their first priority was reducing a heavy federal deficit. As a result, the fiscal axe fell hard on science and technology, with the toughest blows falling on the National Research Council, the government's own major laboratory.

After that, their science track record improved. First they scrapped the infamous scientific research tax

Science policy and the Canadian chemist

Canadian chemists and chemical engineers are naturally concerned about the direction of science policy in Canada. And their views are just as diverse as those in any other scientific discipline. But they aren't particularly vocal about expressing them outside their own coterie. When it comes to telling government what they think about its policies, "We don't have a very active or vocal chemical science community in Canada," admits Anne Alper, executive director of the Chemical Institute of Canada (CIC).

CIC has not been very active in trying to influence science policy in Canada. It had been in the past, says Alper, and she'd like it to be again. In the meantime, CIC tends to be more reactive than active.

Although CIC certainly has budget problems, they are not why the institute hasn't been more outspoken on science policy. It has recently restructured itself into three separate groups under the CIC umbrella. The three are the Canadian Society for Chemistry, the Canadian Society for Chemical Engineering, and the Canadian Society for Chemical Technology. As a result, internal problems command much of CIC's attention. These are expected to be cleared up by next year, Alper says. Then, she adds, CIC will be able to devote more of its attention to external matters, such as science policy.

Three years ago, CIC was instrumental in forming the Action Committee of Science & Technology Presidents (ACSTP). This group of 20 presidents representing various Canadian science and technology societies formed a national lobby to fight for more federal investment in R&D. It intended to hire a professional lobbyist and set up an office to coordinate science policy activities on behalf of more than 100,000 scientists, engineers, and technologists.

But the presidents' action committee is no more. It died, says Alper, because nobody wanted to put their money where their mouths were.

To its chagrin, CIC also found itself in the eye of a hurricane of protest over a study that it helped sponsor. CIC, along with the Canadian Council of University Chemistry Chairmen, the Royal Society of Canada, and the Natural Sciences & Engineering Research Council (NSERC), commissioned a study to chart the future direction of chemistry in Canada, with an eye on the necessary money. The study was led by Howard Clark of Dalhousie University and James A. Morrison, who had previously been at McMaster University.

Their report, "Towards Excellence in Chemistry," was released in September 1986. Later, it became known as the Clark-Morrison report and later still simply as the Morrison report.

Before it was published, the seminal

U.S. study, "Opportunities in Chemistry," or the Pimentel Report, appeared in the U.S. The Clark-Morrison committee relied heavily on the Pimentel Report's statistics and outlook, so much so that it was accused of being the "Canadian Pimentel Report."

That was the least of the report's problems. What shocked the Canadian chemical community were the report's recommendations. It contained nine recommendations, but the basic thrust was selectivity and excellence; that is, more support for the chemical elite at the expense of all others. The report suggested that, to award larger grants to the best researchers, NSERC should cut its number of individual grants 10% per year for five years. The objective: more support for the very best 200 to 300 Canadian chemical researchers.

After the initial shock wore off, the storm of protests began. The simplistic comparison of the U.S. and Canadian situations was the least of them. Most of the responses to the Morrison report condemned its recommendation that funds for the little guy be cut. And most of the responses came from the smaller universities that would suffer the most if the recommendations were implemented.

NSERC, the granting council that helped sponsor the Clark-Morrison study, rejected its proposals outright, saying that smaller chemistry departments had a role to play and should not be squeezed out of the research picture. In fact, none of the sponsoring organizations, including CIC, endorsed the report.

The report did succeed in initiating a lively debate on chemical science policy within the chemical community itself. But so far, there's no outcry for a new study to replace the Morrison report.

Despite the negative response that the Morrison report triggered, ironically some of its recommendations now are coming into play. The government's science policy is leaning toward excellence. Grants for chemical research are becoming more selective. All this has the small universities worried.

On the industrial side, the Canadian Chemical Producers Association (CCPA) has developed a policy paper on research, development, and innovation in the chemical industry. CCPA, says Art LeNeveu, its vice president for business development, thinks that the driving force for chemical innovation is the marketplace.

It has reservations about setting precise targets for R&D expenditures as a percentage of gross domestic product. That concept, says LeNeveu, doesn't take into account differences in a country's size or its market structure. Nor is the concept an appropriate guide for individual industries.

The focus of Canadian science policy should be on the entire innovative process, not just on R&D, according to CCPA. And CCPA doesn't want to see any "self-imposed" impediments placed on access to technology from foreign countries.

credit, a well-intentioned but administratively flawed R&D tax break for companies. It became known as the "$2 billion boondoggle" in Canada and soured an already complacent public on research and research workers.

In March 1987, the federal, provincial, and territorial science ministers signed Canada's first National Science & Technology Policy. The government calls it a "historic agreement." Others call it a "motherhood" statement of broad, general principles with no meat on its bones. That same month, the government launched InnovAction, which it billed as the Canadian Strategy for Science & Technology. It's primarily an umbrella catchphrase under which government has introduced some specific initiatives dealing with science and technology.

Oberle: have to work together to make it happen

Organizationally, the Mulroney government established the House of Commons Standing Committee on Research, Science & Technology. It also created a National Advisory Board on Science & Technology. Board members include leading scientists, educators, industrialists, and union leaders who assess national goals and policies for science and technology, again with an eye on their value to the Canadian economy.

However, the board's outstanding feature is that it is chaired by Prime Minister Mulroney himself. It's the first time that such a board has been chaired by a prime minister. It's also an unmistakable signal that the government is at least trying to improve the climate for science and technology in Canada.

Another strong signal came early last year, when Mulroney personally hosted a National Conference on Technology & Innovation in Toronto. More than 200 of Canada's scientific elite showed up at the by-invitation-only conference. Again, the conference theme was the challenge to Canada's competitive position in international markets and the importance of science and technology in meeting that challenge.

The government used the conference to announce a five-year, billion-dollar boost in government support for science and technology. Of that, $195 million (all figures in U.S. currency; $1.00 = $1.23 Canadian, 1988 average) was earmarked to establish a "centers of excellence" network.

With the program, patterned after a provincial program in Ontario, the government hopes to establish additional links among government, industry, and university researchers. The emphasis, as the name implies, will be on excellence—world-class research to improve Canada's international competitive position. Kenney-Wallace calls the Centers of Excellence

Canada's R&D performance doesn't stack up too well against other nations

	Canada's rank among eight countries[a]
Gross R&D spending as % of gross domestic product	Lowest
Industry-funded R&D[b]	Lowest
Government-funded R&D[b]	Second lowest
Government-performed R&D[b]	Middle
Higher education R&D[b]	Second lowest
Domestic patents granted[c]	Second lowest
International patents granted[c]	Lowest
Advanced degrees awarded[c]	Middle
Scientists and engineers in labor force[c]	Lowest
Number of technology-intensive industries with positive trade balance	Lowest

a Canada, France, Japan, the Netherlands, Sweden, U.S., U.K., and West Germany. **b** Adjusted for gross domestic product. **c** Adjusted for population. **Source:** National Advisory Board on Science & Technology

program "a bold experiment that will expose lab R&D to what's going on in the real world."

An international peer review system will screen applicants, but whether excellence or politics finally decides which projects will be funded remains to be seen. Competition for the limited funds is fierce. About 240 proposals have been submitted. Probably no more than 15 will be funded.

But the Centers of Excellence program has already accomplished something. It has thrown together people who never communicated with each other before. Vincent Wright, a keen observer of Canadian science and technology and editor of the newsletter *Research Money*, thinks that there will be a lot of winners among the many proposals that aren't selected. That's because, by simply collaborating on a proposal, groups of researchers have generated a momentum that won't completely disappear.

The Centers of Excellence program also underscores the government's intention to zero in on excellence in research—the rifle, rather than the shotgun, approach. Targeted research and focused research now are catchphrases in Canadian scientific circles. Yet, the "few versus the many" and the "equity versus efficiency" arguments have not disappeared in Canada. For every scientist who advocates showering most of the scarce funds on the cream of the scientific crop, there is another who says that they should be spread around equitably, regardless of the scientist's track record or stature.

Nor does everyone agree that the focus of supported R&D should be on the market payoff. That, along with an attempt to encourage companies to increase their R&D, is also the goal of a matching funds program. In it, the government matches industry dollar-for-dollar in supporting university research. Largely as a result of the program, private-sector funds to universities increased 18% in fiscal 1988.

But many university scientists are uneasy about the direction in which science policy is heading in Canada. They believe that the government is trying too hard to force a collaborative effort between universities and industry. This approach gives short shrift to basic research, which is, or should be, the major concern of science in universities. As a result, there lurks the danger of conflicting roles.

Another complaint about the matching funds program is that it favors those universities, usually the larger ones, that already have well-established contacts with industry. The smaller schools that have little or no experience collaborating with industry will get the leftovers, if there are any. The complaint goes that it's always easier to nurture existing programs than it is to start new ones. But it's inevitable that there will be more emphasis on university-industry collaboration. It's an inherent part of the government's game plan.

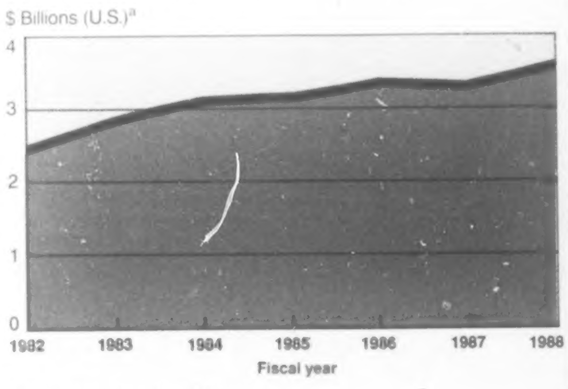
The trend disturbs many university scientists, who feel that the universities are being transformed into the handmaidens of industry. They also are afraid that funding for basic research will suffer.

Most university research money comes from the so-called granting councils. Of the three—the Natural Sciences & Engineering Research Council (NSERC), the Social Sciences & Humanities Research Council, and the Medical Research Council—NSERC has by far the largest budget and is the most critical to university research.

NSERC's budget has increased an average 3.3% per year since 1984, hardly enough to keep up with inflation. Last year, its budget was $289 million. However, most of the increase came through the matching funds program. Its base budget has remained virtually level. The council always has more university researchers clamoring for money than it can possibly handle. In fiscal 1986, NSERC made more than 6000 operating grants, but the average was a weak $18,700.

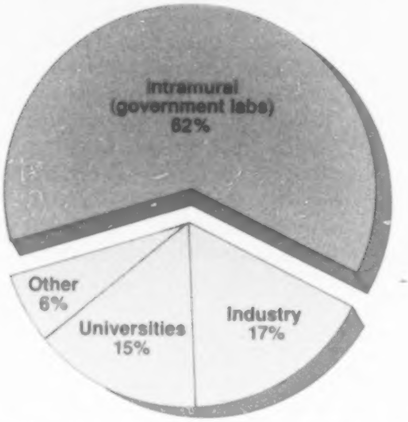
Many in industry believe that, with the exception of their top guns, universities are getting about as

Canadian federal spending on science and technology inching upward



a $1.00 = $1.23 Canadian, 1988 average.
Source: Industry Science & Technology Canada

Canadian government spends most science, technology funding in own labs



Canadian federal government expenditures on science and technology, fiscal 1988 = U.S. $3.58 billion[a]

[a] $1.00 = $1.23 Canadian, 1988 average

Source: Industry Science & Technology Canada

much research money as they can usefully put to work. About 25% of NSERC's operating funds go to only 10% of the top university researchers.

What universities are desperately short of are overhead funds. The federal government will support research, which means primarily salaries and some equipment. It will not pay university overhead costs, such as maintaining existing buildings, building new ones, or providing services that cannot be allocated to any one research project.

One reason is that, under the Canadian constitution, education is a provincial responsibility. The federal government dare not intrude. In Canada, the debate over the division of power between federal and provincial governments is a national pastime. University education and R&D programs often suffer as a result. It's a big problem, but some provinces are beginning to tackle it.

In fact, some provinces are jumping feet first into their own science and technology programs. Ontario had a Centers of Excellence program before the federal government did. It also has an R&D tax benefit program, which will allow companies large tax write-offs on their research investments. And Quebec recently said that it would boost its support of science and technology by $1.13 billion over the next five years. The program includes tax-based incentives, a new technology fund, and a government procurement program designed to stimulate R&D.

Ontario and Quebec are the centers of advanced technology in Canada and have the most ambitious programs to support science and technology. But most other provinces either have similar programs or are considering them. The danger is that, in going their own way, each province may bite off more than it can chew and spread its funds over too many categories of science and technology. "All of them can't be good at all things," says Wright. Nor, he adds, should they.

Rowlinson thinks the direction that both the provinces and the federal government are taking is basically correct. But, he says, "There will always be room for endless discussion on how much money should be allocated."

Canada's budget deficit and debt will command the government's attention immediately. The deficit is running almost 5% of the country's gross domestic product, and the public debt has now reached $260 billion. That's about 54% of gross domestic product, substantially higher than the 40% that it was in 1984. Clearly, Canada's fiscal health is poorer in 1989 than it was five years ago.

The question is not how much more money will be allocated to science and technology. It's more likely to be how to keep in the science and technology envelope the money that's already there. ISTC's Doerr doesn't expect cuts. She thinks that money for science and technology is about as low as it can go.

Regardless of whether she is correct, the next question is how the funds will be allocated. Some policymakers favor reallocation. It is a strong possibility.

The most logical place to look for "spare" money to reallocate is the government's "intramural" R&D funding; that is, its own laboratories. In the current fiscal year, they will receive $2.2 billion, or a hefty 62% of the government's science and technology budget. By some reckoning, they perform only 22% of the country's research. Shifting even 10% of that $2.2 billion would release a sizable $220 million, presumably to the universities.

The federal government's own National Research Council (NRC) is the focus of a lot of attention—and argument. NRC is Canada's largest and most diversified research group, although it does not have the clout that it had in its glory days following World War II. The council has suffered more fiscal damage from government cost cutting over the past several years than any other area of science and technology. Its budget now is only $390 million.

Photo by Yousuf Karsh

Kenney-Wallace: Centers of Excellence a bold experiment

That's only about 18% of the government's spending on intramural science and technology. The rest is consumed in the various "mission-oriented" ministries, such as Agriculture, Environment, and Energy, Mines & Resources.

The large proportion of a government's R&D money going to its own labs is unique to Canada. The country must come to grips with such a lopsided in-house R&D effort. The government has been cutting in-house R&D spending, but more of it is in order. If any money is reallocated, basic R&D at the universities likely would benefit most. If those hard choices have to be made, Kenney-Wallace says that "It is up to us in the business of shaping policy to make sure that existing funds are reallocated into the university R&D base without disrupting existing programs."

But the problems Canada faces with science and technology go beyond just shifting research dollars or nudging research into the areas that will yield the most economic benefit. A major shortcoming is that there is no groundswell of public demand for spending a lot of money on science and technology. To the Canadian in the street, there's no sense of urgency. Life is good. Each has ideas of what the government's agenda should be. Science and technology do not rate high on those agendas. One reason: they remember the $2 billion research tax boondoggle.

Paul Dufour, a former policy analyst at ISTC now on temporary assignment in External Affairs Canada's science and technology division, puts it bluntly. "We don't have a science culture in Canada," he says. Adds Oberle, "Canadians do not yet fully appreciate the significance of the fundamental shift we are experiencing from a resource-based economy to a knowledge-based economy."

To Oberle, one of the greatest challenges facing Ottawa is to make the public more aware of the role that science and technology must play in shaping the country's future. Last year, the government took some very small steps to meet that challenge. It allocated first $8 million, then another $2 million to a program called Science Culture Canada. The money will help to sponsor projects and programs organized by nonprofit groups and a public awareness campaign involving the public and private sectors. It also will help publicize major achievements in Canadian science and technology.

Still another problem is obtaining quality graduate students to foster quality university research. The problem is especially acute in the lesser known schools, away from urban areas. Underlying the problem is that too few undergraduate science students go on to graduate work and that too few high school students choose science and engineering when they hit the universities.

The government has responded with a five-year, $65 million Canada Scholarship Program designed to encourage outstanding high school students to pursue careers in science. But it's only a drop in what the bucket needs.

Perhaps Canada wouldn't have to worry so much about its science and technology policy if it relied more on imported technology. The possibility of following Japan's example hasn't gone unnoticed—or unchampioned: Buy imported technology for Canada, rather than struggle to develop technology in Canada.

Those who advocate such an approach worry that Canada, with its small population and small number of scientists, is spreading its research talent and funds over too wide a base. They say that the country could use its scarce resources better by targeting them at technological areas that Canada absolutely must develop, and buying the rest from other countries.

To some extent, this already is being done. But most experts don't believe that this is the solution to Canada's future economic success. Using someone else's technology usually forfeits to them a two- to three-year lead time to the market. And by the time Canadian industry adapts to the foreign technology it bought, newer and better technology would be available to take its place.

So the quest for a science policy in Canada will continue. The prestigious C. D. Howe Institute, a Canadian nonprofit economic research organization, published a report last month reviewing government policy since 1984 and its possible course over the next few years. The report concludes that the Conservative's accomplishments on science policy since 1984 were "modest." It concedes that the government has at least formed a consensus on the approach to take. But because of fiscal problems, it has not done much to increase funding.

This is not necessarily bad, says the Howe report, because improving the quality and results of Canada's R&D is more important than blindly throwing more money at the problem. And it applauds the government's efforts to forge more government-industry-university linkages. But, says the report, these steps, although promising, "do not yet constitute a viable new approach to science and technology policy in Canada."

The report recommends that a continuing effort to develop a "market-driven" science and technology strategy should be a priority on Mulroney's agenda. Despite some misgivings among scientists, it probably will be.

Throwing money at science and technology may not be the complete answer, but almost everyone agrees that more money wouldn't hurt. They believe that government should look upon science and technology as an investment, not a cost. However, faced with the twin problems of a budget deficit and a huge national debt, the chances that government will appropriate more is slim. The alternative is to reallocate existing funds to get the most mileage out of them. And that's certain to keep the kettle of debate boiling.

It may be next to impossible to get universal agreement on any one science policy in Canada. But, says Wright, it's always hard to reach agreement in Canada. "We can't even agree on a bloody constitution."

Nevertheless, Kenney-Wallace believes that science and technology has now become firmly entrenched as a central part of policy-making in Ottawa. But she calls the next few years the era of hard choices. "There are," she says, "no soft ones left." □

Middle East Chemical Industry Eyes New Products, Markets

Persian Gulf petrochemical industry turns to polymers, fibers, other sectors as it seeks end to dependence on oil, first-generation derivatives

Patricia L. Layman, C&EN London

Nearly 60 delegates met in Manama, Bahrain, late last month to discuss a topic they were all keenly interested in—the petrochemical industry. Basking in the warming late-winter temperatures on this island in the Persian Gulf, dodging a rare but welcome rain shower and high winds that kicked up a foglike haze of sand through Bahrain's capital city, the delegates tackled the topic of Middle East energy and chemicals.

This was the second such seminar sponsored by London-based consultants Chem Systems International. And it built on the philosophy of last year's seminar, to provide a forum for the exchange of ideas between senior personnel both from within the region and from other parts of the world. There were representatives from Arab/Gulf organizations—industrial, governmental, and financial; from Japanese companies and banking consortiums; and from a few assorted western chemical companies.

And just as sand and clay are evolving into sleek high-rise concrete and glass, changing the skyline of Manama, so the petrochemical industry in the Gulf region is working to change from a historical dependence on oil and its first-generation derivatives to the construction of sophisticated downstream businesses in polymers, fibers, and similar sectors. Although phrases such as "Green Party" or "Green politics" may still be unfamiliar to the Gulf, the industry is even tackling the topic of environmentalism, with governmental encouragement.

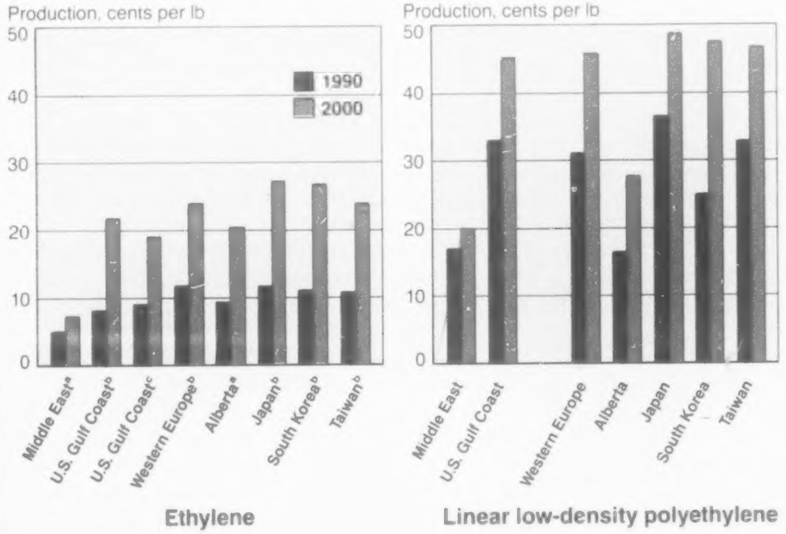
For example, keynote speaker Sheikh Isa bin Abdulla al-Khalifa, undersecretary for Bahrain's Ministry of Development & Industry, brought up the subject, in addition to the business-cycle side of petrochemicals. "Things are good—sales are good, with shortages of capacities," he says. "New projects are being announced, and so on. But how long can the good times last? Have the seeds for future difficulties been sown?"

Several companies are moving toward marketing of new petrochemical products based on scientific research that can be sold for high prices, with applications in a wide variety of uses, he points out. "It is hoped this will lessen vulnerability to the cycles in the petrochemical industry. Even the biggest companies realize the value of a balanced portfolio, with bulk materials and high-value-added products, such as engineering plastics."

An important question that had to be faced, however, was environmental. Sheikh Isa's challenge to industrialists and financiers alike was, "With the surge into plant production, will sufficient attention be given to environmental issues, such as waste emissions, and disposal of wastes, such as plastic wastes?"

Indicative of the growing environmental awareness in the Gulf region, the editorial page of the local paper, the *Gulf Daily News*, applauded Sheikh Isa's concern the day after his address. "The effect of environmental pollution from petrochemical plants, or any other in-

Middle East will stay low-cost producer of ethylene, linear low-density polyethylene through end of century



Ethylene

Linear low-density polyethylene

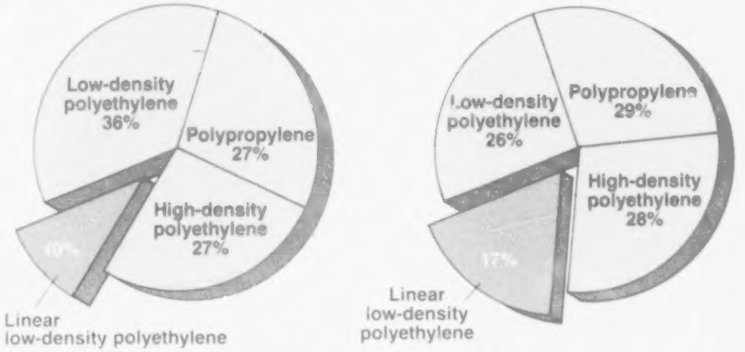
a Ethane feedstock. b Naphtha feedstock. c Propane feedstock. **Source:** Chem Systems International dustrial complex, is an important issue," the editorial read. "Important as it is to any national economy, industry has a duty to safeguard the health of its workers, nearby residents, and the environment in general. Irresponsible action now will only leave a cruel legacy for future generations, creating a pollution time bomb, to explode in years to come," the editorial concluded.

If environmental awareness is one of the hallmarks of a sophisticated petrochemical industry, it will certainly become more significant in the Gulf region over the next decade. For the Gulf's petrochemical industry—already a major industry in Saudi Arabia—is poised to grow quickly.

At least it will if the recommendations of the Qatar-based Gulf Organization for Industrial Consulting (GOIC) are taken up by the various governments in the region, which basically include Iraq, Kuwait, Bahrain, Qatar, Oman, Saudi Arabia, and the United Arab Emirates, which includes Abu Dhabi and Dubai.

At present, said Abdullah Hamad al-Moajil, secretary general of GOIC, the Gulf's percentage of world petrochemical production varies significantly by chemical. For example, of total world methanol production of 18.4 million metric tons in 1987, the Gulf accounted for 9.4%, and in 1990 that percentage is expected to hit 10.1% of total world production of 22.9 million metric tons. The Gulf's share of ethylene production in 1987 was 4.4% (of total world production of 54.6 million metric tons), and will rise in 1990 to 5.4% (of total world production of 70.6 million metric tons). Similarly, its contribution of 4.0% of world polyethylene production of 28.5 million metric tons in 1987 will rise to 4.4% of a 1990 total of 33.2 million metric tons.

On the other hand, the Gulf is low in aromatics production, he says. The region accounts for 0.1% of the world's production of toluene (world total of 14.3 million metric tons in 1987), and the percentage is expected to remain the same as world production grows to 14.9 million metric tons in 1990. The region is boosting production of benzene, however; in 1987, the Gulf accounted for only 1% of world production of 26.3 million metric tons, but that will grow to 2.6% of total production of 29.9 million metric tons in 1990.



LLDPE's share of market to grow fastest through mid-'90s

1988 total polymer demand = 38.7 million metric tons

1995 total polymer demand = 53.4 million metric tons

Source: Chem Systems International

The region had two advantages on which to base its competitiveness: the availability of long-term supply of local feedstock, especially natural gas, and lower cost feedstock and utilities. "The region pretty much decided that the best thing to do with natural gas was to industrialize, not take a course like Algeria, with its liquefied natural gas," says Al-Moajil.

Using natural gas as a feedstock would give the region a solid base to build on. According to GOIC's figures, the Gulf region accounts for 14.1% of the world's natural gas reserves, with a number of countries—Abu Dhabi, Iraq, Kuwait, Oman, Qatar, and Saudi Arabia—having reserves estimated to last for more than 100 years.

GOIC's strategy regarding new projects covers several points. New projects, the consulting group says, should meet existing and expected world consumption, should capitalize on restructuring trends throughout the industry, and should use any relative advantage to compete with less advantaged existing facilities elsewhere in the world. The last two points cannot be separated, Al-Moajil says. "If there are less advantaged facilities, these should be closed down."

With those assumptions in hand, GOIC has recommended a variety of new projects that should be built immediately in the Gulf. It has also put together a list of other projects it feels should be built in the Gulf region sometime in the next 10 years.

For example, Naji Atallah, projects director of GOIC, says the time is

Polyethylenes top Middle East capacity and demand

Thousands of metric tons per year	1985		1990		1995	
	Capacity	Local demand	Capacity	Local demand	Capacity	Local demand
LDPE	414	265	454	335	514	380
LLDPE[a]	510	36	560	75	550	95
HDPE[a]	230	110	470	180	600	220
Polypropylene	60	147	60	190	445	230
PVC	185	320	415	440	490	560
Polystyrene	25	95	150	160	240	220

Note: Includes Turkey, excludes Egypt; LDPE = low-density polyethylene, LLDPE = linear low-density polyethylene, HDPE = high-density polyethylene, PVC = polyvinyl chloride. a Swing capacity (capacity can be used for either HDPE or LDPE). **Source:** Chem Systems International

Consultants see Middle East expansion opportunities

	Recommended for immediate implementation		Recommended over next 10 years
	Total capacity, thousands of metric tons per year	Location	Total capacity, thousands of metric tons per year
Methanol	1500	Qatar, Oman, and United Arab Emirates	
Propylene	200	Bahrain	800–1000
Urea			3000
Polypropylene	100	Bahrain	500–800
Propylene oxide	80	Saudi Arabia or Bahrain	80–100
High-density polyethylene	90	Qatar	
Toluene	40	Saudi Arabia	
***p*-Xylene**	32	Saudi Arabia	
***o*-Xylene**	40	Saudi Arabia or Iraq	
Styrene-butadiene rubber	40	Saudi Arabia	
Nylon	40	Saudi Arabia or Iraq	
Dinitrotoluene	10	Iraq	
Toluene diisocyanate	40	Saudi Arabia or Iraq	
Terephthalic acid	50	Saudi Arabia	
Polyester	50	Saudi Arabia	
Phthalic anhydride	40	Saudi Arabia or Iraq	
Petroleum coke	300	Bahrain, Kuwait, or United Arab Emirates	
Acetic acid	80	Saudi Arabia, Qatar, or Bahrain	
Formaldehyde	30	United Arab Emirates, Saudi Arabia, or Bahrain	
Lube oil additives	35	United Arab Emirates and/or Saudi Arabia	
Acrylic fibers			50–70
Butene and butadiene			100
Isobutene			15–20

Source: Gulf Organization for Industrial Consulting

right for Bahrain to go ahead with a $200 million polypropylene plant "as soon as possible. It is the perfect time, because polypropylene is a growing market and the product is in very high demand." In fact, consulting engineering company Bechtel is doing a feasibility study for the Bahrain government for a plant that would produce between 100,000 and 200,000 metric tons a year, fed with propane.

Of course, other Gulf countries, including Saudi Arabia and Kuwait, are planning similar plants. High world prices, boosted by heavy demand, mean the cost of a new plant could be paid off in two years, predicted David F. Oxley and Geoff Pyke, Chem Systems directors, at the seminar.

The Middle East also has investment opportunities in such downstream products as methyl *tert*-butyl ether (MTBE). Pyke points out that the real importance of MTBE relates to its value as a substitute for other octane enhancers, such as tetraethyl lead and benzene, in the production of gasoline.

The market potential for the compound is dramatic. According to Chem Systems data, just concentrating on the U.S. and Western Europe, the consumption of MTBE as a gasoline additive is currently more than 4 million metric tons per year. This market could reach 15 million metric tons by 1995, two thirds in the U.S., one third in Western Europe. MTBE demand in the U.S. could be nearly 10 million metric tons per year by 1995, says Pyke, but domestic supply is unlikely to be much higher than 3 million metric tons, so imports will have to be substantial. Similarly, in Western Europe, demand in 1995 will be about 5 million metric tons, met largely by imports. Much of the imported product—into either region—will come from new projects.

MTBE certainly offers further investment potential for the Middle East, given projected demand growth and need for additional capacity, Pyke says. The region already has a ready availability of feedstocks. And current pricing developments will favor the butanes route. Of course, he adds, negative factors exist, including the substantial capital investment required by a field butanes project, and the uncertainty of the MTBE price outlook.

MTBE plants will find solid export markets, in a variety of geographical regions. However, some caution may be needed in building up investment in other export-oriented products, because a major export destination, the Far East, is building itself up, warns Alan Plaistowe, Chem Systems president.

The Far East has traditionally been a market for exports from Western Europe and the Middle East. Notes Plaistowe: "The East Asian market is an extremely important one to producers in other areas of the world and has served as the preeminent target market for trade during the 1980s." That worked during the surplus years of the early and mid-1980s, he says, but when capacities turned snug and producers concentrated on supplying domestic markets, supplies to the East Asian countries tapered off and prices rose—"significantly higher than could be found in the domestic markets of the U.S. and Western Europe."

Those high prices, however, increased the interest and determination of producers of petrochemicals in Asia to expand capacities. The result is a significant growth of petrochemical investment in South Korea, Taiwan, and Southeast Asia, particularly Thailand.

The Middle East and the U.S. most likely will become the swing suppliers—East Asia will look to these areas to supply incremental volumes. The Middle East, especially, should stand to benefit. This is due to the competitive cost advantages Chem Systems believes the Middle East has and will continue to have through the end of the 1990s, with production costs significantly lower than those elsewhere. □

AAAS report spells out plan to achieve scientific literacy
Page 22

MARCH 13, 1989

CHEMICAL & ENGINEERING NEWS

Global Warming

Complex
interactions
are the key
Page 25

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MARCH 13, 1989

News of the Week

- **International conference held last week in London on saving the ozone layer leaves key issues unresolved.** Page 4
- **Group of authors and publishers in New York City calls for use of acid-free paper for first printing of quality hardcover books.** Page 5
- **Group formed by Natural Resources Defense Council launches campaign to limit pesticide residues in food.** Page 5
- **President Bush reaffirms his commitment to science in visit to exhibition of Westinghouse High School Talent Search finalists at National Academy of Sciences.** Page 6
- **Senate subcommittee heard charges last week that chemicals used in advanced composites have caused illness in several hundred aerospace workers.** Page 6

Business

Soda ash and caustic soda consumption is continuing strong, but chlorine demand is slumping; European Community is planning to open market for energy to freer competition; titanium dioxide supply will stay tight through the next decade. **Page 9**

Government

Question of pesticide safety for children that is raised in environmental group study is disputed by EPA, others; House Democrats find Bush budget lacking, suggest solutions; European Community's 1992 plan will alter its scientific and technological relations with U.S. **Page 13**

Science/Technology

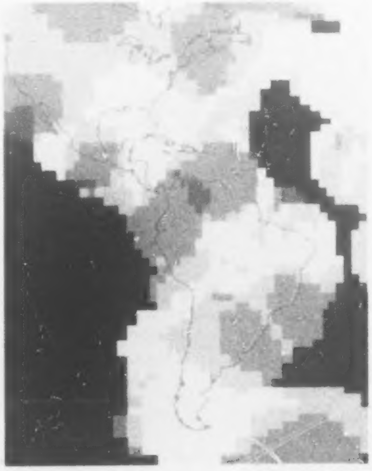
Membrane techniques for liquid separations are derived from industrial gas separation methods. **Page 20**

Education

"Science for All Americans" report from AAAS describes efforts to achieve national educational reforms, gives guidelines to attack scientific illiteracy problem in U.S. **Page 22**

Books

Second edition of popular book on writing offers useful advice and examples to take writers through step-by-step process. **Page 45**



Cover: Computer-generated diagram shows temperature trends during past century. Map diagram courtesy of NASA Goddard Institute for Space Studies

Special Report

Knowledge of the greenhouse effect on global warming has progressed during the past few years, but unraveling the complex reactions that are involved remains a challenge. **Page 25**

Letters 2

Concentrates
Business 7
Government 12
Science/Technology 19

The Departments
ACS Comment 47
ACS News 47
Meetings 50
Newscripts 64

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LETTERS

Steam cleaning toxic waste

SIR: In the article "Low-cost cleanup of toxic petrochemicals" (C&EN, Dec. 12, 1988, page 24), Rudy Baum explains a novel way of cleaning up toxic waste by injecting steam through solvent-contaminated soil.

I salute Kent S. Udell, James R. Hunt, and Nicholas Sitar for the work. However, Rudy Baum states, "The process completely removed the xylenes, which came as something of a surprise because the compounds have higher boiling points than water."

It shouldn't be a surprise. The steam and xylene are producing an azeotrope which boils off at 94.5 °C. The composition of this azeotrope is 60% xylene and 40% water. When cooled, the upper layer contains 99.95% xylene and 0.05% water, and the lower layer contains 0.05% xylene and 99.95% water.

David L. Parkinson
Milwaukee, Wis.

Heat from radioactive waste

SIR: Edward J. Fritz (C&EN, Dec. 12, 1988, page 3) can take comfort in knowing that scientists in the field of radioactive waste management are already aware that much heat will be generated by the radioactive wastes buried underground. The effect of this heat on geological structures has been the subject of several decades of experimentation at the salt mines of Ft. Lyons, Kan., and Asse, West Germany, at the Stripa iron mine in Sweden, and in other places. Dissipation of heat enters into the calculations of spacing the wastes underground. France, which has made the most progress in actually dealing with nuclear waste, is deliberately keeping its high-level wastes in shallow underground storage for 30 to 50 years so that they can be packed more densely when buried deep. We will also wait this long, though by default. Incidentally, there is no groundwater to speak of in Yucca Mountain.

The really long-lived wastes, the transuranics, generate so little heat that they can be buried at any time. The waste isolation pilot plant repository in New Mexico is ready to receive them now. Only political obstacles remain—transfer of 10,000 acres by Congress between two government agencies, updating of an environmental impact statement, and satisfying New Mexico's demand for $300 million "for roads and bridges."

No, Jerry March (C&EN, Dec. 12, 1988, page 3), future generations will not curse us for a legacy of properly disposed nuclear waste. If anything, they will laugh at our squeamishness, just as we snicker at the fears of earlier generations concerning steam boilers, automobiles, electricity in the home, and so on. These technologies have indeed proved dangerous, but we all accept their risks as manageable, and exceeded by their benefits. However, future generations may curse our continued use of irreplaceable oil, gas, and coal for power and steam generation while nearly inexhaustible reserves of uranium and thorium exist.

John E. Tanner Jr.
Idaho National Engineering Laboratory, Idaho Falls

Liability insurance

SIR: Let's put a better perspective on Gordon Nelson's comments on ACS professional liability insurance (C&EN, Jan. 16, page 50). All working chemists, according to current law and regulation, can be charged in civil and criminal actions by the Environmental Protection Agency and a myriad of other state and federal agencies. The individual—from bench to top manager—shares responsibility along with the corporation.

Can you afford not to have professional liability insurance?

Robert D. Athey Jr.
El Cerrito, Calif.

Balanced education

SIR: I would like to respond to Hugh D. Crone's letter (C&EN, Jan. 16, page 4) about my letter on the Priestley Medal address. Although he claims to have identified the roots of our educational problems—that we have made a distinction between science and the humanities—he is not correct that this is "the" or "a" problem. Show me one experiment that can explain the Renaissance or derive a language. These are but a few examples of the realistic distinctions between the sciences and nonsciences. Not every subject is amenable to scientific methods. To believe so, as much of our society does, is dangerous. It can lead to an absolute belief that science and technology can solve all problems, a pseudoreligious faith. It also causes society to regard anything nonscientific as being less worthy. That is where the problems in education have arisen.

Both arenas deserve equal weight and emphasis; they are not mutually exclu-

NASA photo

SPECIAL REPORT

Global Warming

The future climate of our greenhouse globe will result from complex, poorly understood interactions

Bette Hileman, C&EN Washington

We all live in a global greenhouse. The air, clouds, soils, vegetation, and structures that surround us reflect and absorb and re-emit radiant energy across the electromagnetic spectrum that arrives from the sun. About a third of incoming solar energy is directly reflected back to space, and the remaining energy increases the temperature of the absorbing gases, liquids, and solids. The absorbing bodies reradiate to space, at longer wavelengths of the infrared portion of the spectrum, a portion of their increased energy. But as was recognized a century ago, trace gases in the atmosphere, such as carbon dioxide, strongly absorb infrared radiation, thus trapping a greater portion of the sun's energy. Consequently, Earth's surface temperature is raised about 35 °C over what it would be if no trace gases were present, making our planet habitable.

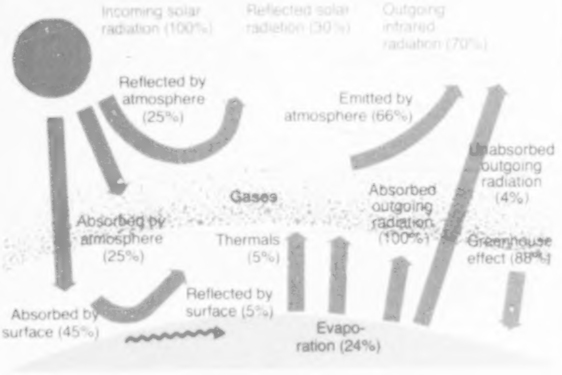
This thermal radiation environment, Earth's greenhouse, has changed over geologic time, and is changing today. We have been altering our environment for thousands of years, and continue to do so apace. Yet, until the industrial revolution, our changes usually were local, or at most regional, in scope. Now, the changes are global, and we are beginning to understand how complex and interconnected Earth's systems are, and how today we are involved in a great experiment to test the response of those systems to changes in greenhouse gases—the trace-gases that absorb infrared radiation.

Our inadvertent experiment has no overall design. We vaguely know where the control panels for operating the greenhouse's many systems are. Understanding the dynamic response of Earth's systems, and more important, their mutual interaction, remains a profound challenge.

Some atmospheric and ocean scientists have been guardedly warning us for several decades about the risks of our experimentation. But only in the past few years has the theory about greenhouse warming been elevated to a matter of serious concern. Only recently has research activity in this area been given high priority. It now involves scientists from all over the world in international cooperative programs. The U.S. government has assembled into a combined budget request all of its research programs related to global change. The Secretary of State is suggesting that the time has come to initiate measures that would reduce greenhouse warming. Last year, for the first time, bills designed to curb greenhouse gases were introduced in Congress, but action has not yet been taken.

Though knowledge of the greenhouse effect has progressed on some fronts during the past few years, the advances have shown a steady increase rather than a radical jump. Probably there are four major reasons why the greenhouse effect has aroused so much scientific and public interest.

Trace gases in Earth's atmosphere trap heat near the surface


Incoming solar radiation (100%)
Reflected solar radiation (30%)
Outgoing infrared radiation (70%)
Reflected by atmosphere (25%)
Emitted by atmosphere (66%)
Unabsorbed outgoing radiation (4%)
Gases
Absorbed outgoing radiation (100%)
Absorbed by atmosphere (25%)
Thermals (5%)
Greenhouse effect (88%)
Reflected by surface (5%)
Absorbed by surface (45%)
Evapo-ration (24%)

Carbon dioxide, water vapor, chlorofluorocarbons, methane, and other greenhouse gases are nearly transparent to the visible and near-infrared wavelengths in sunlight, but they absorb and re-emit downward a large fraction of the longer infrared wavelengths emitted by Earth.

The schematic shows the one-dimensional (vertical only) results from a radiative-convective model of energy transfer. The several pathways and forms of energy flow as measured by percents of incoming solar radiation are indicated. The incoming solar radiation on the left-hand side is predominately short wavelength. One quarter is reflected back to space and another quarter is absorbed by atmospheric gases, increasing their temperature. The remaining 50% reaches Earth's surface, where 5% is reflected to space. Of the 45% of solar radiation absorbed as heat energy by Earth, 5% is transferred to the atmosphere by thermal conduction and atmospheric convection (thermals) and 24% is transferred through surface evaporation of water and condensation within clouds to produce atmospheric warming.

Because of the greenhouse heat-trapping effect, the atmosphere radiates large amounts of long-wavelength energy downward to Earth's surface. Consequently, the long-wavelength radiant energy warming Earth is nearly double (88% versus 45%) that received directly from the sun. This warms the surface, which in turn emits 104% of the original incoming energy as long-wavelength energy. A small part of this, 4% of the incoming solar energy, escapes directly to space. The remainder is trapped by atmospheric gases. The relatively warm atmosphere radiates 66% as long-wavelength radiation to space, thus maintaining its energy balance.

Source: Stephen H. Schneider, National Center for Atmospheric Research

First, some climate modelers now claim that the first signal of global warming has been detected. Meteorologists have long recognized that climate trends cannot be inferred from relatively short-term weather events, no matter how extreme. Yet, a strengthening statistical trend of warming global climate during this decade is becoming more difficult to explain by chance.

Second, the discovery of a stratospheric ozone hole in the austral spring over Antarctica and evidence that it is caused by release of chlorofluorocarbons (CFCs) into the atmosphere have led to the belief that man-made alterations in the atmosphere can have unpredictable and serious consequences. F. Sherwood Rowland, University of California, Irvine, and Mario J. Molina, formerly with that university, predicted in 1974 that CFCs would cause a very slow loss of stratospheric ozone over the entire globe. But no one had foreseen that a sudden drop of 50% could occur in the Antarctic ozone concentration.

Third, scientists have come to realize that concentrations of greenhouse gases in addition to carbon dioxide in the atmosphere also are rising rapidly. The combined warming effect of all these greenhouse gases will produce sooner the same radiative warming that was predicted for the more distant future from the long-established carbon dioxide increases alone.

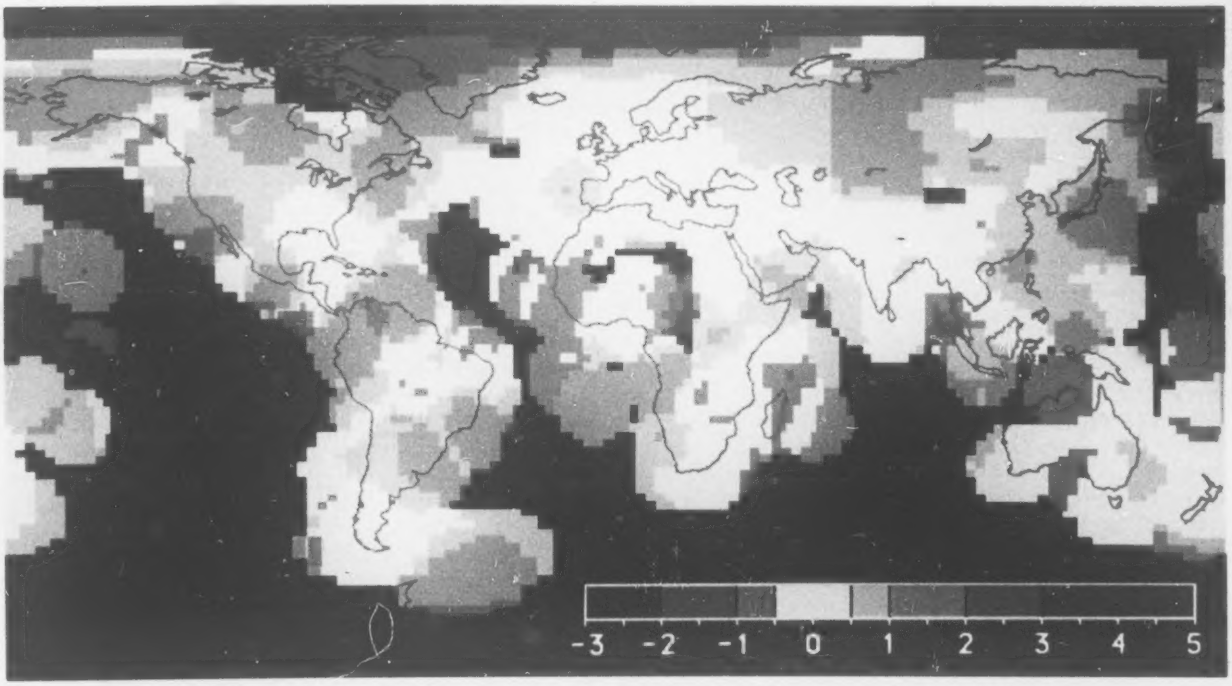
Fourth, a steady accumulation of understanding in many areas of earth science is giving some scientific leaders the hope that a broad-based, well-coordinated, major research program could within a few decades fill in many of the important gaps in understanding of climate change. This hope is supported by the recent availability of monitoring devices of increased capabilities, planned launches of satellite platforms suitable for extensive remote sensing, and anticipated leaps forward in computing power.

Concern over the greenhouse effect reached a crescendo last summer. In the U.S., it was fueled primarily by the record-high temperatures in many regions and very severe, widespread drought.

Global warming caused by the widespread presence of greenhouse gases in Earth's atmosphere is one of the most well-established theories in atmospheric science. There is also little controversy that if present emission trends for greenhouse gases continue, they will cause some warming at some time during the next century. What is controversial is how much climate change can be expected, when it will occur, and where its effect will be most evident.

There is also disagreement about whether the extra carbon dioxide and other greenhouse gases that have been added to the atmosphere since the industrial revolution have already warmed the climate beyond the level of natural variability. Analyses of Earth's surface temperature over the past century have been made by two groups, the National Aeronautics & Space Administration's (NASA) Goddard Institute for Space Studies (GISS) and the Climatic Research Unit in East Anglia, England. Using in part the same database but different methods of analysis, they find that global temperatures rose about 0.5 °C in the past century even when almost all possible corrections were made in the data sets for urban heat island effects. They also find that the past 10 years have been the warmest decade on record.

An analysis of data from balloon-borne instruments (radiosonde data) performed by James K. Angell, a research meteorologist at the National Oceanic & Atmospheric Administration's (NOAA) Air Resources



NASA photo

Computer-generated diagram shows temperature trends from 1880 to 1985. Changes are shown only for those areas where temperatures had been measured by 1925 or earlier. The temperature analysis and diagram were done by James E. Hansen of NASA Goddard Institute for Space Studies

Laboratory, corroborates this conclusion. He finds that global surface temperatures have risen 0.08 °C per decade since 1958, which is consistent with the GISS and East Anglia studies.

Despite a near consensus that global warming has occurred, "most climatologists do not yet proclaim that the observed temperature changes this century were caused beyond doubt by the greenhouse effect," says Stephen H. Schneider, head of the interdisciplinary climate systems section of the National Science Foundation's (NSF) National Center for Atmospheric Research (NCAR). For example, even though Angell has found global warming since 1958, the evidence for ascribing it to the greenhouse effect is conflicting.

It is highly likely that the overall warming he observed is outside the range of natural variability in his data. But his data show a slight decrease in temperature in the north polar and north temperate zones from 1958 to 1987 and a slight decrease in temperature at both polar zones from 1973 to 1987. This is significant because most climate models of greenhouse warming show the greatest temperature increase at the poles. "In view of the pros and cons, I believe it is premature to state categorically that a greenhouse effect is already being observed," Angell says.

Thomas R. Karl, a NOAA meteorologist, is also skeptical. He thinks that even though the most careful analyses show global warming in the past century, the uncertainties are still too great even to say that the 1980s are without doubt the warmest decade we've ever seen. There could still be uncertainties that stem from changes in data-gathering methods, he says.

In contrast, according to James E. Hansen, director of GISS in New York City, there is an extremely high degree of probability that Earth is already experiencing greenhouse warming. The chances of having five years of record-breaking heat occur in the 1980s without greenhouse warming are extremely slim, he says.

Regardless of whether they believe that greenhouse warming is now affecting climate, most climate modelers agree that if present emission trends for greenhouse gases continue, global temperatures will rise 2 to 6 °C over the next century and that the most recent results suggest a warming of 3.5 to 4.5 °C. Though it looks small, a global temperature change of even 1 to 2 °C is severe. According to Schneider, "A sustained global increase of more than 2 °C above present is unprecedented in the era of human civilization." At the extreme of the most recent ice age 18,000 years ago, the globe was only about 5 °C colder than it is today, but at no time in the past million years has the sustained temperature been more than a few degrees higher than it is now. Global temperatures that occurred from about 1550 to 1850 during the Little Ice Age were just 0.4 °C below current levels.

At first glance, understanding greenhouse warming appears fairly simple. On the basis of current trends of human population growth, fossil fuel burning, agricultural development, and land use patterns, scientists predict future levels of carbon dioxide and other greenhouse gases in the atmosphere and compute how much extra infrared radiation they will absorb and radiate back to Earth. The ability to describe the temperatures found within the planetary atmosphere of a biologically inert planet, based upon its gaseous composition, is quite advanced. Models have been used to calculate the surface temperatures of our nearby planetary neighbors to a high degree of accuracy, as confirmed by measurements. But because of its coupled oceans, atmosphere, ice sheets, volcanoes, and, most important, living organisms, describing how Earth's climate responds to atmospheric changes is exceedingly difficult.

Accurate prediction of greenhouse warming involves understanding interactions among the inconstant sun and the highly complex systems of the atmosphere, biosphere, geosphere, Earth's water system, and glaciers and ice. For example, changes in just one system, such as carbon dioxide levels in the atmosphere, can cause changes in other systems, such as the growth rates of phytoplankton or trees, which in turn can have a variety of effects on the atmosphere, some of which may cause additional warming and others which may cause cooling. These are known as positive and negative feedbacks—circular processes in which two or more elements of a system affect each other cyclically, sometimes amplifying the original effect, and sometimes decreasing or negating it. The most important feedback system is the ocean, which covers nearly three quarters of the globe. The ocean's physical, chemical, and biological dynamical responses are very poorly understood. Yet understanding ocean dynamics is crucial for predicting ordinary weather as well as perturbations brought about by greenhouse warming.

Rapidly rising trace gases

One of the few results of greenhouse effect research that seems fairly straightforward and noncontroversial is that levels of naturally occurring atmospheric trace gases, such as carbon dioxide, methane, and nitrous oxide, have risen sharply over preindustrial levels while CFCs and other halocarbons released by industrial societies have become a new class of radiatively important trace gases. Since the first systematic measurements were made at Mauna Loa in Hawaii in 1958, carbon dioxide levels have increased from 315 ppm to 350 ppm and the rate of increase has speeded up in recent years. From analysis of air trapped in ice cores in Greenland and Antarctica, it is known that preindustrial levels were about 280 ppm. Therefore, carbon dioxide levels have already risen at least 25%. In these ice core records, which go back as much as 160,000 years, no fluctuations of carbon dioxide have been larger than this, and the current carbon dioxide level is the highest it has been for at least 160,000 years.

The bulk of extra carbon dioxide that has been added to the atmosphere has come from the burning of fossil fuel and massive deforestation. Rapid deforestation in the tropics, by reducing the total amount of carbon that is sequestered in vegetation and other biomass, now contributes about 10 to 30% as much as fossil fuel emissions do.

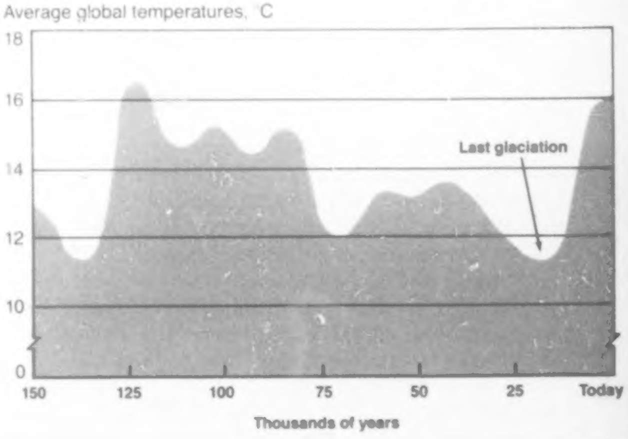
There are two main reasons for uncertainty in these estimates, says Richard A. Houghton, a senior scientist at Woods Hole Research Center. The rate of deforestation is not known at all accurately. In Brazil, it is estimated that an area the size of Pennsylvania is burned or cut down each year, but there are no surveys for the rest of the world. And it is not known how much carbon is stored in forests. Forests in temperate latitudes may on balance be expanding their total biomass after being seriously depleted during the past century, and boreal forests may be accelerating their growth rates for reasons that are poorly understood. So no certainty exists as to how current changes in forestation are affecting levels of atmospheric carbon dioxide.

Deforestation adds carbon dioxide to the atmosphere in two ways. Most of the trees are burned or decomposed by bacteria, emitting carbon dioxide directly to the air. The deforested land ends up as barren soil, grassland, or cropland that absorbs much less carbon dioxide than a forest does. A rapidly growing rain forest can fix annually between 1 and 2 kg carbon per square meter, whereas cultivated fields fix only 0.2 to 0.4 kg per square meter, which is recycled annually.

Even though their concentrations are much lower, taken together the trace gases methane, nitrous oxide, tropospheric ozone, and the halocarbons are now estimated to trap about 60% as much long-wave radiation as does carbon dioxide. They absorb in a window of the electromagnetic spectrum from 7 to 13 μm, where carbon dioxide and water vapor are relatively transparent. Water vapor traps radiation with wavelengths below 7 μm, and carbon dioxide absorbs in the region above 13 μm. Because their atmospheric levels are rising rapidly and because each molecule of these trace gases absorbs more infrared than a carbon dioxide molecule, their combined greenhouse warming effect is estimated soon to equal that of carbon dioxide.

Veerhabadrhan Ramanathan of the University of Chicago has calculated that if emission trends con-

Global warming of 2 to 6 °C would make Earth the warmest it has been in 150,000 years



NASA photo

Radiosonde balloon-borne instrument packet is being released to measure temperature, pressure, and relative humidity at different heights in the atmosphere. Such instruments are sent up from 63 locations around the world each day

tinue, the greenhouse effect of these other trace gases, when added to that of carbon dioxide, will amount to an "effective" doubling of carbon dioxide levels by the year 2030, 50 years sooner than the level of carbon dioxide alone is likely to double.

Levels of methane, one of the fastest growing of the greenhouse gases, have soared in recent years. Each year, an additional 50 million tons remains in the air, making the current concentration, now about 1.7 ppm, more than twice as high as it was before the industrial revolution. Since systematic measurements of atmospheric methane began in 1979, levels have grown more than 1% annually.

This rate of increase combined with its high efficiency as a greenhouse gas increases the importance of understanding methane in the biosphere. Studying the concentration and isotopic composition of methane in air bubbles trapped in polar ice cores allows scientists to determine when atmospheric methane began to increase, how rapidy it is increasing, and what some of its principal sources are.

More than half of the methane released to the atmosphere comes from the action of anaerobic bacteria on plant material, primarily in the stomachs of ruminants such as cows and sheep and in the guts of termites, and in rice paddies and wetlands of all types in all latitudes. Methane also is released from coal mines, leaks in natural gas pipelines, leaks of natural gas associated with oil production, and decomposition of organic matter in landfills. In addition, it is emitted from incomplete combustion of vegetation in forest or range fires or when land is cleared for agriculture. Thus, the rapid increase of atmospheric methane likely results in part from increases in agricultural production. The methane from most of these sources has a distinctive ratio of ^{13}C to ^{12}C.

Most of the methane is removed from the troposphere by oxidation with hydroxyl radical, giving methane a lifetime of about nine years. Residual quantities of tropospheric methane escape to the stratosphere, where it is destroyed. The destruction of methane by hydroxyl radical proceeds more rapidly for ^{12}C than for ^{13}C. Thus, atmospheric methane is enriched with more ^{13}C than would be expected from the average isotopic ratios of methane sources. Taking these differences into account, it is possible to create an isotopic mass balance for atmospheric methane from all known sources and its hydroxyl radical sink. This allows improved emission estimates to be made for some sources, such as biomass burning, where obtaining reliable emission rates has been problematic.

Concentrations of nitrous oxide, though not increasing as fast as methane, are climbing steadily, rising from 280 ppb at the turn of this century to 303 ppb at present. This results from the injection of 5 million tons of nitrous oxide into the atmosphere each year.

Nitrous oxide molecules, whose average tropospheric lifetime is 150 years, play havoc with the atmosphere in two ways. They contribute to greenhouse warming and supply nitrous oxide to the stratosphere, where it destroys stratospheric ozone. The only known atmospheric sink for nitrous oxide is its breakdown to nitric oxide in the stratosphere by ultraviolet light.

The major sources of increased nitrous oxide are biomass burning and artificial fertilization of soils, rather than, as previously thought, the burning of fossil fuel. According to Ronald G. Prinn, atmospheric chemist at Massachusetts Institute of Technology, burning of forests and agricultural land produces a considerable quantity of nitrous oxide, but an equal amount comes from the soil for a few years after the burn.

The database for tropospheric ozone is not nearly so complete as it is for other greenhouse gases because most ozone monitoring networks cover only urban areas and are operated mainly during the summer to study city smog. Nevertheless, tropospheric ozone levels over North America and Europe seem to have increased between 1 and 2% annually since the late 1960s.

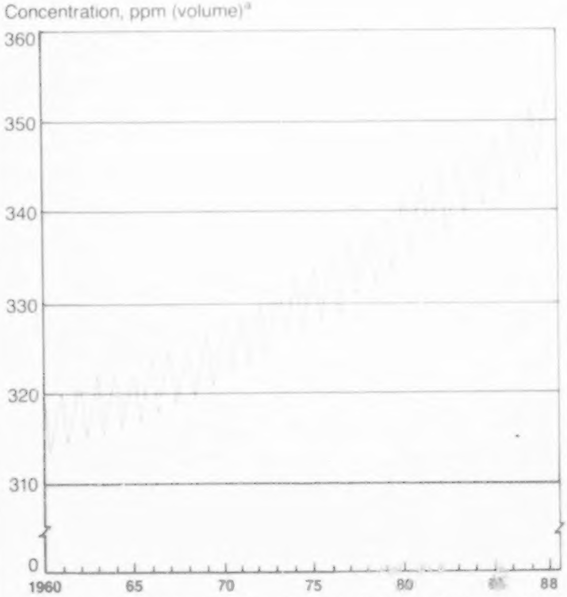
The primary source of excess tropospheric ozone is reaction between the hydrocarbons and oxides of nitrogen emitted from the burning of fossil fuels. It may also be produced biogenically from the reaction between nitric oxide made by soil microbes and terpenes and other hydrocarbons released by trees. However, recent research by Steven C. Wofsy and his colleague Warren A. Kaplan of Harvard University indicates that tropical forests, rather than a net source, are a large net sink for tropospheric ozone. Therefore, deforestation in the tropics is probably adding to the ozone problem for two reasons. The removal of forest reduces the uptake of ozone, and the associated biomass burning increases the production of ozone precursors.

Ozone's effect on surface warming is complex because at some heights in the atmosphere it does not act as a greenhouse gas. An ozone molecule in the upper troposphere produces much more surface warming than does a molecule at the surface or in the mid- or upper-stratosphere. But the scarcity and high variability of data on ozone concentrations in the upper troposphere prevent scientists from determining a trend. Ozone depletion in the lower stratosphere may induce some surface cooling, whereas depletion in the upper stratosphere may cause warming. Andrew A. Lacis of GISS found that ozone trends during the 1970s would have caused a net cooling at Earth's surface.

Concentrations of chlorofluorocarbons (CFCs) and halocarbons are rising faster than those of most greenhouse gases because their annual rate of release has been increasing in recent years. The concentrations of CFC-11 ($CFCl_3$), which was used as an aerosol propellant and is still used as a blowing agent for foam insulation, and CFC-12 (CF_2Cl_2), a refrigerant, are growing about 5% annually. The concentration of CFC-113 (CCl_2FCClF_2), a solvent for cleaning electronic microcircuits, is soaring at an 11% annual rate.

Levels of several other halocarbons also are increasing rapidly. These are carbon tetrachloride, which is used for making CFC-11 and CFC-12, and methyl chloroform, which is employed as a solvent for cleaning sheet metal and a cleaning agent in the electronics industry; and the fire retardants, halon 1301 (CF_3Br) and halon 1211 (CF_2BrCl). Because these gases contribute to greenhouse warming as well as destroy stratospheric ozone, controlling their emissions would help solve two problems simultaneously.

Atmospheric carbon dioxide is up more than 10% since 1960



[a] Measured at Mauna Loa, Hawaii. **Sources:** Charles D. Keeling, Scripps Institution of Oceanography; National Oceanic & Atmospheric Administration

Because of the halocarbons' effect on the stratospheric ozone layer, the consumption of many of them is being cut back under the Montreal Protocol on Substances That Deplete the Ozone Layer. Earlier this month, the 12 European Community countries and President Bush called for a worldwide phaseout of CFCs by the end of the century. (For more on the phaseout, see page 4.)

Model predictions

The three-dimensional models used to calculate global temperatures and precipitation with increased levels of carbon dioxide and other greenhouse gases in the atmosphere are known as global climate models. These models, as they have evolved over two decades of development, are among the most sophisticated used in any of the geophysical sciences today. In these models, Earth's surface is divided into 800 to 11,000 rectangles or grid points. The atmosphere over each grid point is divided into between five and 15 layers.

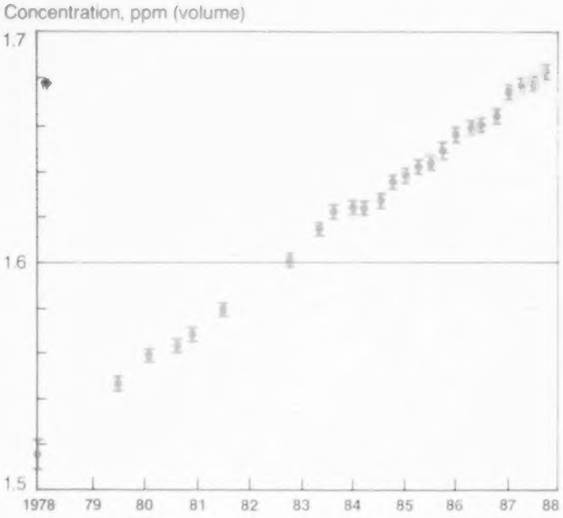
The flow of atmospheric gases from each of these cells into adjacent cells is calculated using the basic laws of thermodynamics and hydrodynamics. These laws include the conservation of mass, energy, and momentum, and the gas laws. Laws governing the transfer of electromagnetic radiation through a heterogeneous gaseous medium relate incoming solar radiation with changes in the contents of each cell and the amount of radiation reaching Earth's surface. Reflectivity of various surfaces, such as ice, snow, oceans, clouds, and vegetated and unvegetated lands, are included.

Supercomputers are used to solve equations that estimate winds, temperature, sunlight, relative humidity, and precipitation for each grid point on the globe. Cloudiness is estimated uniformly for each grid point from its temperature and relative humidity. To predict the results of an effective doubling of carbon dioxide in the atmosphere, the modeler increases the amount of carbon dioxide and other trace gases in the model. This raises the calculated surface temperatures and alters cloud cover, wind, and patterns of precipitation.

Four modeling groups in the U.S. are working with global climate models. Each of them has developed a basic model and is constantly working to refine the model to make it more realistic.

All of the models developed so far have some basic problems. One is a lack of spatial resolution. Although several thousand grid cells may seem like a great many, a variety of atmospheric chemistry and physics goes on within the actual atmosphere that each grid cell represents. For example, storm fronts, major mountain ranges, urban or industrial pollution, atmospheric chemical reactions, and changes in cloud type and cover all routinely occur on spatial scales less than the

Atmospheric methane shows linear increase in past decade

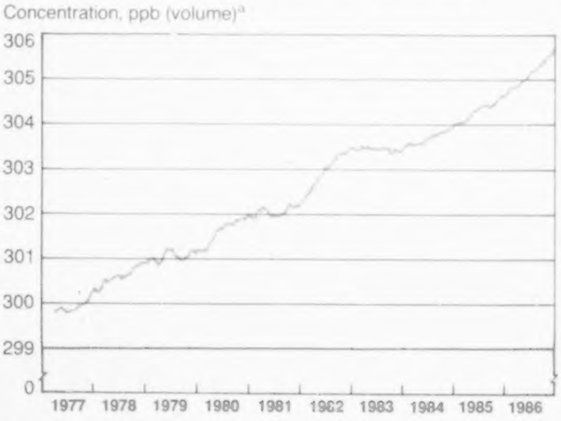


Source: Donald R. Blake and F. Sherwood Rowland, University of California, Irvine

size of a grid cell. Modelers greatly simplify the underlying science to represent these subgrid-cell influences.

Even though the spatial resolution in the global climate models is inadequate and a large number of parameters are omitted entirely, many scientists have some confidence in the models because they produce quite accurate simulations of some phenomena. For example, when the models are used to predict summer and winter temperature extremes for very large areas all over the globe, the results are similar to measured temperatures. Calculated temperatures for various levels of the atmospheres of Mars and Venus are also very close to the measured temperatures. Furthermore, the models' calculations of temperatures in the Mesozoic Era and of glacial/interglacial cycles match reasonably well with what is known about past temperatures from studies of ocean sediments, ice cores in Antarctica, tree rings, and other evidence.

Nitrous oxide levels continue steady rise



a Measured at various locations in Northern Hemisphere. **Source**: Ray F. Weiss, Scripps Institution of Oceanography

Results of the global climate models are similar in a number of respects. Most of them predict that increased levels of greenhouse gases would have warmed Earth about 1 °C during the past century, in comparison with the actual change of about 0.5 °C. Their predictions of increased global temperatures and changed precipitation patterns resulting from a doubling of carbon dioxide concentration agree within about a factor of two. And their predictions of seasonal and annual averages of temperature over large areas often match well. The models agree that after the climate system comes to equilibrium, warming will be greater at high latitudes and the tropics will warm only slightly. Less agreement on precipitation patterns is found among these models.

A Department of Energy (DOE) comparison of results from global climate models prepared in 1988 by Stanley L. Grotch of Lawrence Livermore National Laboratory concludes that for regions smaller than a continent, "the correlations observed between different model predictions are often very poor." Also, none of the models yields the upper tropospheric cooling that NOAA's Angell has found in his analysis of radiosonde observations.

Nevertheless, according to Schneider, these models give considerable evidence that, over the next 50 years or so, subtropical monsoonal rain belts will be wetter, growing seasons at high latitudes will be longer, springtimes in high- and mid-latitudes will be wetter, midsummer conditions in some mid-latitude areas will be drier, and extreme heat waves will occur more often.

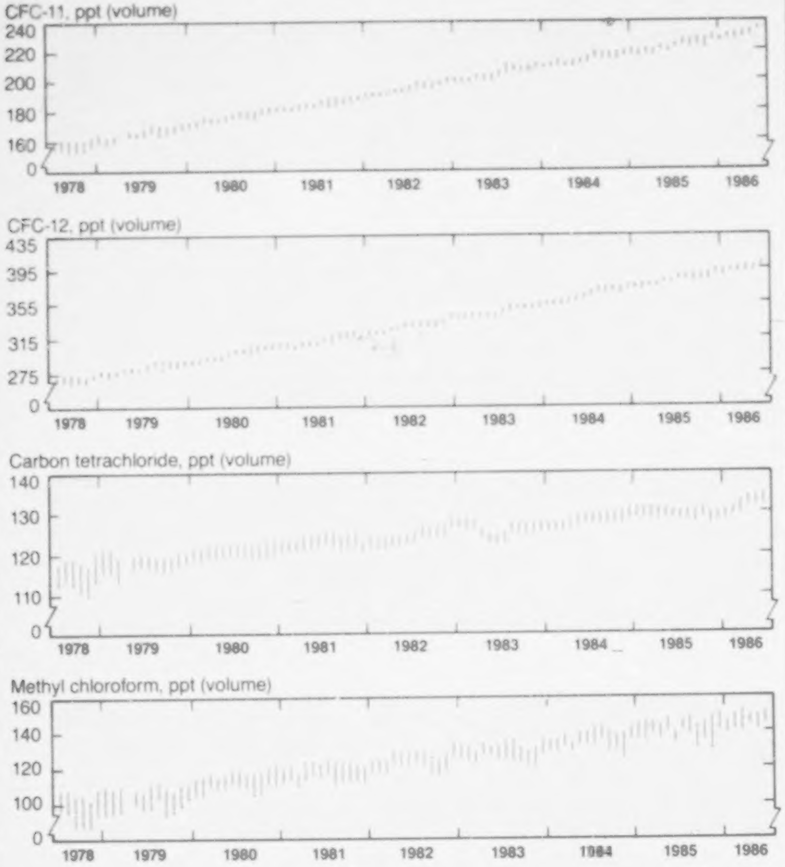
It appears that scientists can look at model results and come to opposite conclusions. Schneider finds the global climate models meaningful because over very large areas of Earth, their predictions of temperature agree so well with each other and with observations. DOE's Frederick A. Koomanoff, who directed the agency's carbon dioxide research division until recently, considers the models poor because their predictions sometimes disagree sharply for regions smaller than a continent and some of their simulations of climate for subcontinental regions in past years conflict with observations.

All climate modelers admit, moreover, that the models have serious deficiencies that could cause variability in their predictions of greenhouse warming and could make the results unreliable, especially for subcontinental regions. A number of those factors that have not been accounted for in the models could amplify greenhouse warming, others could moderate it, and some may have only a negligible effect.

Unknown greenhouse players

Factors not accounted for or that are described very crudely in the global climate models include clouds; ocean heat capacity, microscopic life, and deep circu-

Atmospheric halocarbons have been increasing steadily



Since mid-1978, the Barbados station of the Global Atmospheric Gases Experiment (GAGE) has measured the trace gases trichlorofluoromethane (CFC-11, or $CFCl_3$), dichlorodifluoromethane (CFC-12, or CF_2Cl_2), carbon tetrachloride (CCl_4), and methyl chloroform (CH_3CCl_3). Qualitatively similar results are obtained from the other GAGE stations located in Tasmania, Samoa, Oregon, and Ireland. At each station each of these gases is measured 12 times daily at ground level. **Source:** R. Prinn, P. Simmonds, F. Alyea, D. Cunnold, A. Crawford, P. Fraser, and R. Rasmussen.

lation; variability of solar energy output; the biogeochemical carbon cycle; and the relationship between temperature and methane releases from the Arctic permafrost.

Probably the largest surprises could come from what is not known about the effects of the oceans and clouds on greenhouse warming.

The oceans are still basically uncharted territory. Readings of atmospheric circulation and temperature are made in many places all over the world every day. Readings of ocean circulation and temperature are taken only sporadically. Many years may pass before measurements are repeated in the same place. Consequently, climatologists know much more about the dynamics of the atmosphere than about the dynamics of the oceans.

Partly as a result of this lack of data, the vertical movements of the water by which the ocean takes heat from the surface down into its interior and in the process delays the warming of the atmosphere are not included in the models. Also, the models assume that heat transport of the ocean's surface and its salinity remain essentially constant. Several eddies that stretch along 25 to 50 km are combined into one large eddy and described by only one parameter.

However, these omissions may be a serious flaw. Trying to understand global warming without factoring in deep ocean circulation and changes in ocean heat transport may be analogous to trying to understand how a bird flies without studying its wing structure. "No feedback on the greenhouse effect from ocean heat transport may be a reasonable assumption for short time scales—one or two decades—but in the long run, this is the biggest uncertainty in climate models," Hansen says.

Wallace S. Broecker, geochemist at the Lamont-Doherty Geological Observatory at Columbia University, has evidence that changes in deep ocean circulation have been responsible for rapid climate changes—changes that took place in a century or two. Data from polar ice cores, ocean sediments, and bog mucks indicate that Earth's climate "has actually jumped from one state to another. It is a system that when nudged has done some outrageous things," which involve large-scale oceanic and atmospheric reorganization, Broecker says.

For many years scientists believed that Earth's climate had changed gradually in the past. They based this conclusion on the $^{18}O/^{16}O$ record in Foraminifera shells found in cores taken from the ocean floor. The variations in this ratio are the direct result of the waxing and waning of the ^{18}O-deficient continental ice caps—which are of necessity gradual processes even if other climate changes are rapid. (Ice caps are deficient in ^{18}O because they are formed from water that has evaporated, which is itself deficient in ^{18}O because of its heavier mass. As ice caps grow, locking up water deficient in heavy oxygen, the ocean water and the Foraminifera living at that time become enriched in heavy oxygen.)

In contrast, the variations in species distribution recorded in the deep sea muds in the North Atlantic and especially evidence from holes drilled in the

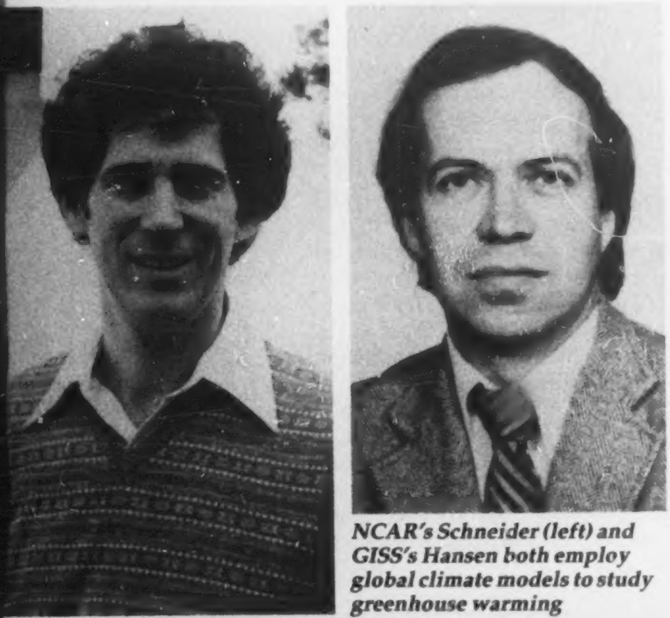
Concentrations, lifetimes of greenhouse gases vary widely

	Atmospheric concentration, ppm (volume)	Atmospheric lifetime
Carbon dioxide	350	~500 years[a]
Ozone	0.02–10	less than a few hours[b]
Methane	1.7	7–10 years
Nitrous oxide	0.31	150 years
CFC-11 ($CFCl_3$)	2.3×10^{-4}	75 years
CFC-12 (CF_2Cl_2)	3.8×10^{-4}	110 years

[a] Combined lifetime for atmosphere, biosphere, and upper ocean. [b] Although lifetime of ozone itself is less than a few hours, lifetime of O_x (ozone + oxygen atoms) depends strongly on location, varying from about an hour in the upper stratosphere to months in the lower stratosphere to hours to days in the troposphere. **Source:** Department of Energy

Greenland ice cap present a different story. The annually deposited layers in the ice cores contain bubbles of air trapped at the time the ice was formed. The carbon dioxide content of this air is a measure of the greenhouse capacity of the atmosphere at that time. (It has varied by as much as 20% from warm to cold periods in geologic history for reasons that are not understood completely.) The layers in the ice cores also contain a record of the oceans' temperatures in the form of the ratio of isotopically "heavy" (water enriched in ^{18}O) to "light" water in the ice and from the amount of dust in the ice. (When the world's temperature is higher, more heavy water evaporates, making snow that contains more heavy water. Usually a colder world is dustier because it supports less vegetation, and the dust helps to cool surface temperatures.)

Each of the last five glacial cycles ended abruptly, Broecker says. For example, as Earth was coming out of its most recent glacial period, the ice and ocean sediment cores show an abrupt warming followed by a brief period of intense cold in the North Atlantic, followed once again by warming. "The typical leap involves a 6 °C change in air temperature, a fivefold change in atmospheric dust content, and a 20% change in the carbon dioxide content of air," Broecker notes. Earth's system seems to resist change until it is pushed beyond some threshold.



NCAR's Schneider (left) and GISS's Hansen both employ global climate models to study greenhouse warming

Broecker speculates that the engine for these leaps was an abrupt change in deep ocean circulation—what he calls the oceans' great conveyor system—which is governed by the temperature and salt content of the water. This deep current system moves 20 times more water than all the world's rivers combined.

He believes that during glacial periods, the deep current as it operates today was shut down, cooling the North Atlantic and the lands adjacent 6 to 8 °C and allowing tundra to take over where forest had once been. As Earth was coming out of the ice age, the sharp changes were probably caused by flips of ocean circulation back and forth between two modes of operation that are self-stabilizing until affected by external changes, Broecker explains. The last flip was initiated by changes in the outlet for the meltwater from the great ice sheet covering North America. The final period of intense cold in the North Atlantic, Broecker says, commenced when all the water from the southern margin of the Laurentide ice sheet started flowing out the St. Lawrence, instead of the Mississippi, making the North Atlantic much less salty than usual.

There is no Laurentide ice sheet to melt during the next century. But ice could melt in other areas, such as Antarctica or Greenland, and initiate changes in deep ocean circulation. The sudden cooling that occurred as Earth was coming out of the most recent ice age shows that climate is a system of entangled and interlocking parts that makes it capable of behavior that does not appear in the current generation of computer models. Because of their design, these models are very limited in their ability to predict the kinds of phenomena Broecker warns of.

Unfortunately, with today's knowledge there is no way of knowing the probability that a buildup of greenhouse gases will jolt the ocean-atmosphere out of its current mode. Additionally, climate modelers agree that predictions of subcontinental effects will remain highly uncertain until a coupled ocean-atmosphere model can be created. "There is no way we can predict local climate until we understand the architecture of the atmosphere and oceans better," Broecker explains.

The only way to incorporate deep ocean circulation and heat uptake into atmospheric global climate models is by creating coupled ocean-atmosphere models. However, two practical problems stand in the way of such models. A deeper understanding of the dynamics of the ocean itself and more computer power than is now available are needed.

Another aspect of atmosphere-ocean interactions that is essential to understand is heat storage by the oceans. Heat uptake by the oceans can delay, though not eliminate, greenhouse warming. But, by delaying the climate change at Earth's surface, it confounds scientists' attempts to infer global climate sensitivity to greenhouse gases from observed climate change.

To determine heat uptake by the oceans, climate modelers need to have ongoing temperature and current measurements over all the oceans at various depths, especially in the upper 1000 meters. The World Ocean Circulation Experiment, an international effort that begins next year, will collect such data. Hansen believes that heat uptake is the most important measurement needed to improve knowledge of global climate sensitivity.

To describe oceans accurately, measurements must be made over much shorter distances than is necessary for the atmosphere. A data set for oceans comparable to those used to describe large-scale atmospheric systems needs an observation point about every 25 km. Because the ocean can take centuries to complete some cycles, compared with the atmosphere's day or weeks, the model must be run for a longer simulated time period.

The net result is that a coupled atmosphere-ocean model would require a much larger data set than today's global climate models. Current supercomputers are not capable of handling such a large amount of data. It is likely to take 10 to 20 years before such a model can be developed, Hansen predicts.

Unfortunately, clouds are another major factor standing in the way of reliable predictions of greenhouse warming. In a warmer world, more water will evaporate from the oceans. What is not known is whether this additional water vapor will condense to create more clouds or whether it will tend to remain as vapor. And if more clouds are created, it is not known what types of cloud will dominate.

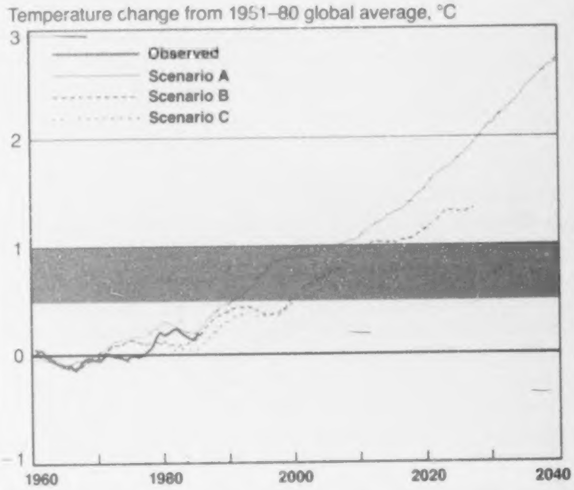
Clouds both warm and cool Earth. Bright low- and midlevel clouds, by reflecting short-wave radiation from the sun, tend to cool the planet, whereas high cirrus clouds, by reradiating long-wave radiation from their surface, act like a greenhouse and warm it. Until recently, it was not known whether the net overall effect of clouds is warming or cooling.

However, Ramanathan believes that clouds have a net cooling effect globally of about four times as much energy as would be trapped by doubling carbon dioxide levels. In mid- and high latitudes, the net cooling from clouds is large, but over the tropics, their cooling is nearly canceled by heating. He obtained these results from readings taken by two satellites launched for Earth Radiation Budget Experiment—a system of satellites that provides data on incoming and emitted radiation.

Ramanathan's results suggest that if clouds in a warmer greenhouse world tend to become more like those in the tropics, then the clouds will amplify the warming. But if the clouds tend to become more like those now in high and mid-latitudes, they will reduce the warming. The output from most current climate models shows clouds as a positive feedback, strengthening greenhouse warming. According to Ramanathan, it will take a few years to modify the models to reflect new knowledge about clouds.

Historical data published in 1987 by Ann Henderson-Sellers of the University of Liverpool, England, also indicate that clouds may compensate for greenhouse warming, at least in part. She analyzed records of cloud cover from 200 stations in three continents dat-

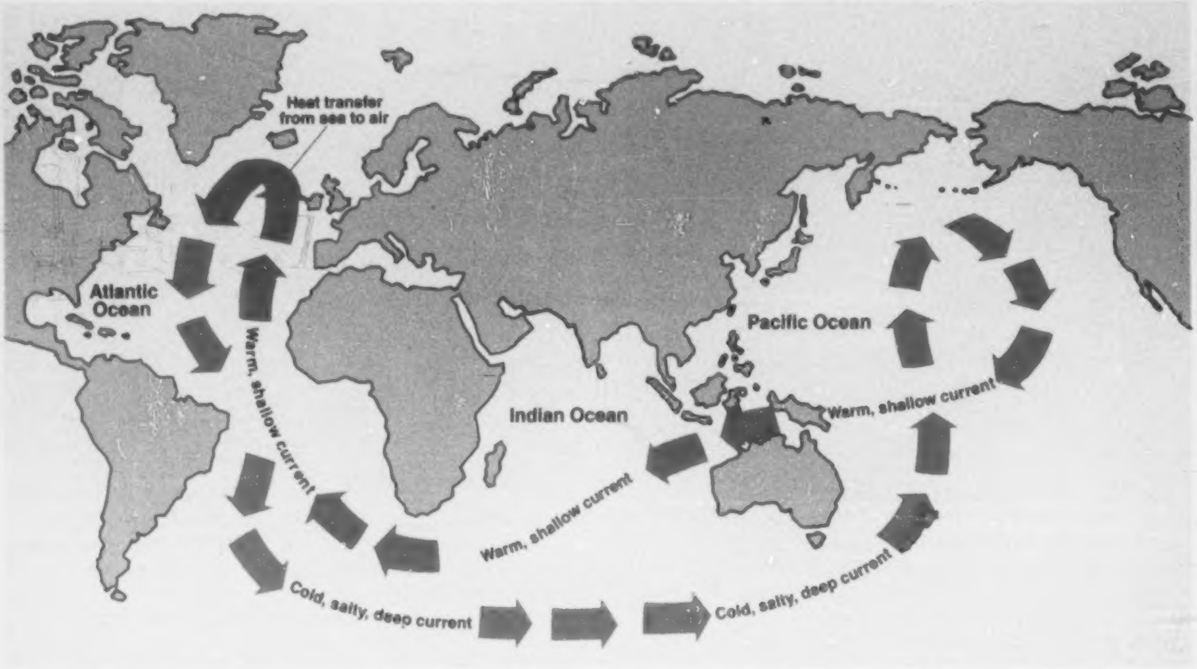
Extent of global warming will depend on how greenhouse gas emissions grow



Temperature changes with three different emission scenarios for greenhouse gases are predicted with the climate model used at the National Aeronautics & Space Administration's Goddard Institute for Space Studies. The "observed" graph line shows the observed average global surface temperature change as a five-year running mean with the 1951–80 mean as the zero point. The line for scenario A shows the future temperature change if growth rates of greenhouse gas emissions typical of the 1970s and 1980s continue indefinitely. The annual rate of growth averages about 1.5%, so the net greenhouse radiative effect increases exponentially. The graph line for scenario B shows temperature changes if trace gas growth rates decrease, so that the annual increase of the greenhouse radiative effect remains about constant at the present level. The line for scenario C shows temperature changes if greenhouse gas emissions are cut drastically so that the greenhouse radiative effect ceases to increase after the year 2000. The [illegible] band shows the range of estimated temperatures [illegible] highest average global temperatures during the [illegible] previous interglacial periods, about 6000 and [illegible] years before the present, respectively. Because [illegible] temperatures for all three emission scenarios rise [illegible] this band, Earth, even with drastic emission reductions is predicted to grow at least as warm as it was during these interglacial periods.

Source: James E. Hansen, NASA Goddard Institute for Space Studies

An ocean current transfers heat from low-latitude to high-latitude air in the Atlantic



Currently, the Atlantic loses more water by evaporation than it gains by precipitation and continental runoff. To compensate for the transport of water vapor through the atmosphere from the Atlantic Ocean to the Pacific Ocean, a large current, which carries 20 times more water than the world's rivers combined, brings salty, deep water from the North Atlantic, where it is created, to the Pacific, where it upwells. The system is self-stabilizing. On the return trip, the current carries heat from the tropical areas of the Atlantic to the region around Iceland. There, the warm current meets the cold Arctic air from the north and is cooled, becoming more dense. The extra density makes the water sink to the abyss. It then returns to the Pacific as a deep current. This system, too, is self-stabilizing. Data from ice cores and ocean sediments indicate that, as Earth was warming from the most recent ice age, meltwater from the great Laurentide ice shoet in North America started flowing out the St. Lawrence River instead of the Mississippi River and made the North Atlantic much less salty than usual. This reduced the density of the North Atlantic current and prevented it from sinking, disrupting the conveyor system and causing sudden cooling in Northern Europe. This period of intense cold in Northern Europe, but not in North America, is called the Younger Dryas. It ended about 700 years later when the Laurentide glacier had melted enough to drastically reduce the flow of fresh water from the St. Lawrence.

ing back to the turn of the century. In most regions, the cloud cover was greater during warmer periods, suggesting higher temperatures would bring more clouds. Her results, however, say nothing about what type of clouds would dominate in a warmer world—whether the increased cloud cover is low and mid-level or high. Also, there are difficulties in these historical data because methods of observing and reporting the amount of cloud cover have changed.

Methane's role

The role that methane plays in global warming is a major uncertainty in climate models that has received a great deal of attention lately. Methane is of particular concern because each molecule is 15 to 30 times more effective than a carbon dioxide molecule in greenhouse warming, and even when methane reacts along with nitrogen oxides in the troposphere, it leads to the production of another greenhouse gas, ozone. Analysis of ice cores shows that in Earth's past carbon dioxide and methane concentrations in the atmosphere rose and fell together for unknown reasons. Therefore, methane undoubtedly amplified the greenhouse effect of carbon dioxide. Variations in methane levels are hypothesized to have resulted from the expansion and contraction of Arctic and boreal peatlands during glacial changes.

Enough of the world's carbon resides in boreal and Arctic regions that these ecosystems are of particular importance to understanding the response of methane sources to climate change. Northern peatlands and bog regions are a significant source of methane emissions. Also, according to Robert C. Harriss of the Institute for the Study of Earth, Oceans & Space at the University of New Hampshire, methane is present

Photos by Patrick M. Crill

Patrick M. Crill of the University of New Hampshire found large emissions of methane from the northern peatlands of Minnesota. In photo at left, Crill uses plastic syringe to grab an air sample from the headspace of a methane flux chamber located in a bog in Marcell Experimental Forest, Itasca County, Minnesota. To calculate methane emissions from bog, air samples so obtained are analyzed for methane using a gas chromatograph equipped with flame ionization detector. As part of this study of methane emissions, soil is cored (photo at right) to check plant species in the Red Lake peatlands in Minnesota. In background is a gas filter correlation infrared analyzer, which continuously monitors methane concentrations within a flux chamber

in large quantitites as "frozen" clathrates or methyl hydrates (rigid cages of water molecules that trap molecules of methane) in subsurface sediments on the continental slopes under the polar seas and in layers of permafrost on land. Warming of the Arctic could allow these deposits to melt and release methane, but the quantity of release and its timing are open questions.

In an effort to understand the potential that northern peatlands have for adding to methane levels, Patrick M. Crill of the University of New Hampshire and his colleagues measured methane emissions from boreal peatlands in Minnesota. They found that the emissions rose significantly with soil temperature. One open bog showed a 74-fold increase in emissions with a 15 °C increase in temperature. The average emissions measured in their experiments, if it occurred over the total area of peatlands north of 40° N for four months of the year, would yield 72 million metric tons of methane per year. This amount would have about one quarter the greenhouse effect as the 5200 million metric tons of carbon dioxide emitted to the atmosphere annually by fossil fuel combustion. Harriss, however, has found in the Yukon delta region that methane emissions in the ecosystem come primarily from the periphery of the tundra ponds, where the vegetation and soil around the edges of the ponds is slumping into the water. Because of the inhomogeneity in emissions, extrapolating local emission measurements to the entire polar region requires a great deal of care.

Several factors could help mitigate the methane emissions that could result from global warming. Increased reactivity of the atmospheric gases that accompanies warming could lead to higher production rates for hydroxyl radicals, which destroy methane in the troposphere. Also, higher temperatures could reduce the extent of wet, anaerobic soils in the Arctic and sub-Arctic, thereby reducing this area's potential to produce methane.

Until more research is completed, it won't be known whether methane emissions could increase future global warming and thus should be included in climate models. But levels of methane in the atmosphere are now rising so rapidly and there is such a large storehouse of it within the Arctic permafrost that it looms as a rather formidable wild card in the greenhouse game.

The biogeochemical carbon cycle

Uncertainties in the biogeochemical carbon cycle are another important source of error in global climate models. The carbon cycle is not simple. It is composed of several linked cycles, operating on different time scales, by which carbon moves from the atmosphere to the biosphere or geosphere and eventually to the atmosphere again.

There are a number of major pathways carbon can take. As carbon dioxide, it can be photosynthesized by land- or water-based plants. The plants are then ingested by animals, and some of the carbon returned to the atmosphere as the carbon dioxide product of digestion. This is generally a short-term process.

In another important but much longer route, dead

Plankton's effect on clouds is uncertain

During greenhouse warming, phytoplankton may possibly affect cloud cover and thus create a negative or positive climate feedback. Some species of phytoplankton excrete dimethylsulfide (DMS) into the seawater. Part of the DMS then enters the atmosphere and oxidizes to form sulfate aerosols, which serve as condensation nuclei for developing cloud droplets.

In 1987, Robert J. Charlson of the department of atmospheric sciences at the University of Washington reported a direct correlation between DMS levels and the number of cloud nuclei over portions of the Pacific. At about the same time, James A. Coakley Jr., of the National Center for Atmospheric Research found from satellite observations of oceanic clouds that particles from the exhaust of ships increased the reflectivity of the clouds directly over the ships' paths. This suggests that the sulfate particles oxidized from DMS also might enhance cloud's reflectivity. Charlson has calculated that increased cloud nuclei from DMS could cool Earth significantly—a hypothesized 30% increase in nuclei would cool Earth 1.3 °C, but the relationship between changes in sea surface temperature and DMS releases to the air and their influence on the number of cloud condensation nuclei is not known.

Experimental data on DMS production as a function of temperature are conflicting. When Timothy S. Bates of the National Oceanic & Atmospheric Administration's Pacific Marine Environmental Laboratory plotted DMS emissions against solar radiation, he found that where DMS emissions are higher, solar radiation is more intense. However, he does not think his observations are necessarily true for the worldwide population of plankton. Robert Delmas of the Laboratory of Glaciology & Geophysics of the Environment in Grenoble, France, has noted an opposite trend. He found that the 20,000-year-old Antarctic ice that existed during the most recent ice age had a higher than average number of methane sulfonate particles. This may indicate that the DMS production goes up in a colder world, amplifying the cooling.

Stephen E. Schwartz of the environmental chemistry division at Brookhaven National Laboratory also has cast doubt on the theory that DMS emissions from phytoplankton regulate mean global cloud reflectivity. He tried to find a relationship between man-made sulfur dioxide emissions in the Northern Hemisphere (which are oxidized to sulfate particles in the atmosphere) and cloud reflectivity (albedo). He reasoned that if sulfate particles increase cloud albedo, they would do so more over the Northern Hemisphere, where the sulfur dioxide emissions have risen sharply in the past century, than in the Southern Hemisphere, where they have risen much less. But he found no differences in cloud albedo that could be attributed to the sulfur dioxide emissions. Without further data, it is impossible to tell whether plankton are a positive or negative climate feedback.

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marine plants and animals fall to the sea floor and are buried in silt. Their soft tissues may then form kerogen (fossil organic matter contained in a mineral matrix) in coal, natural gas, and petroleum.

In a third major pathway, carbon dioxide from the atmosphere or from the decomposition of plants dissolves in clouds or rainwater to form carbonic acid. This dissolves carbonate and silicate minerals to produce bicarbonate ion, which is carried in runoff into streams and rivers and into the ocean, where it may be incorporated into the skeletal tissues and shells of marine organisms. As these animals die, most of their skeletal remains are deposited on the seafloor and eventually form carbonate rock.

Carbon deposits in the oceanic crust are transported over geologic time to active subduction zones at the margins of continental plates, where they are thrust deep under the continental plates. There, the carbon-containing minerals are heated. Ultimately, carbon, as carbon dioxide released from the minerals, escapes to the atmosphere through volcanoes and bicarbonate-rich mineral springs. This process takes tens of millions of years and has kept the atmospheric level of carbon dioxide relatively constant. According to Michael B. McElroy of Harvard University, "The average carbon atom has made the cycle from sediments through the more mobile compartments of the Earth, back to sediments, some 20 times over the course of Earth's history."

A few quantitative facts are known about man's influence on the carbon cycle. It is known that about 5 billion metric tons of carbon as fossil fuel are burned each year and about half of this carbon ends up as atmospheric carbon dioxide, as measured by NOAA's global network of monitoring stations. But what happens to the remaining half is not clear. All of it may end up in the world's oceans by being dissolved or absorbed by aquatic plants. Or some large fraction may enter the land-based biological systems—the plants and soils. If a significant fraction ends up in land-based plants or soil each year, the land-based biosphere must show a net increase. Unfortunately, there is no good monitoring system for either the carbon content of the oceans or Earth's vegetation on land.

Also, it is not known how carbon storage in forests or in the ocean will change in a warmer world with higher levels of atmospheric carbon dioxide. There is some evidence that trees store more carbon when atmospheric carbon dioxide levels are higher because they may grow faster.

The annual fluctuation of global carbon dioxide concentrations is greater now during the Northern Hemisphere summer than it used to be. This may indicate that more carbon dioxide is being taken up by the biota during its period of fastest summer growth.

However, many biologists do not believe that higher carbon dioxide levels increase overall growth rates of wild vegetation. For instance, Houghton says the amount of water and nutrients available to plants in the wild is a much more important limiting factor than the availability of carbon dioxide.

Even less is known about how increased carbon dioxide levels and higher temperatures will affect the storage of carbon dioxide in the ocean. The growth of phytoplankton depends on sunlight, surface water temperature, and the availability of nutrients. If the ocean surface were to warm uniformly with higher global temperatures, the ocean would be more stratified and nutrients would upwell to the surface less. But there is no reason to believe that surface warming with higher global temperatures would be more uniform than it is now. It may be even more uneven, energizing currents and stimulating primary productivity.

In addition to uncertainties associated with ocean circulation and heat uptake, clouds, methane, and the carbon cycle, there are many other influences on global warming that can't now be accurately treated in global climate models. Some of them are changes in terrestrial ecosystems, moisture convection, vertical distribution of ozone, the solar output, volcanic aerosols, man-made aerosols, Earth's reflectivity (albedo), and rates of decomposition of dead organic matter in the soil.

Even if enough were known about all of these factors to describe them in the global climate models, some experts argue that local effects of greenhouse warming may still be very hard to predict. Scientists who regularly work with atmospheric models realize that small differences in initial conditions can make a

The sun is an inconstant energy source

The amount of solar radiation reaching Earth and Earth's changing orientation to the sun have been the major causes for climatic change throughout its history. If the sun's electromagnetic radiation declined 5 to 10% and there were no other compensating factors, ice would engulf the planet in less than a century. Even though the sun's irradiance is extremely important to the climate on Earth, changes in irradiance are not included in current global climate models.

Although no scientific theory exists to predict future changes in solar output, the effect of changes in Earth's orbit as it travels around the sun is beginning to be understood. During the past million years, Earth has experienced 10 major and 40 minor episodes of glaciation. All appear to have been controlled by three so-called orbital elements that vary cyclically over time.

First, Earth's tilt changes from 22° to 24.5° and back again every 41,000 years. Second, the month when Earth is closest to the sun also varies over cycles of 19,000 and 24,000 years. Currently, Earth is closest to the sun in January. This month-of-closest-approach factor can make a difference of 10% in the amount of solar radiation reaching a particular location in a given season. Last, the shape of Earth's orbit varies from being nearly circular to being more elliptical with a period of 100,000 years. The climatic cycles caused by these orbital factors are called Milankovitch cycles after the Serbian mathematician Milutin Milankovitch, who first described them in 1920.

Even though studies of ocean cores over the past 20 years have shown that these orbital changes are the principal cause that determines the times of glaciation, the exact mechanisms by which Earth responds to the orbital changes have not been determined. Scientists believe that orbital changes alone do not cause the vast climate shifts associated with glaciation and deglaciation. Feedbacks, such as changes in Earth's reflectivity, dustiness of the atmosphere, and the carbon dioxide and methane content of the atmosphere, act together with orbital changes to enhance global warming and cooling. The levels of carbon dioxide and methane, as shown in ice core measurements, decrease during times of glaciation and increase during warming periods, indicating that they play a part in cooling and warming. (It is not known exactly how or why their concentrations rise and fall.)

Earth is now in a cooling phase of its natural cycle, and temperatures would be expected to decline somewhat over the long term, if other factors, such as greenhouse warming, were not having an opposing effect. Greenhouse-related climate changes will probably be much stronger over the next half millenium than those expected from orbital changes. Nevertheless, it is important to understand the Milankovitch cycles and how they have affected Earth's climate in the past. The various feedbacks that operated to warm Earth in the past will probably operate to help warm Earth in the future. Also, if scientists know how much Earth would have cooled without greenhouse warming, they can determine more precisely the warming that has been caused by radiative gases. In addition, once the Milankovitch cycles are well understood, it might even be possible to use the greenhouse effect productively to offset undesirable cooling from orbital changes.

Superimposed on the Milankovitch cycles are changes in the sun that occur over days or months or a few years. For example, Karin Labitzke of the Free University of Berlin and Harry van Loon of the National Center for Atmospheric Research have linked an 11-year sunspot cycle to some general weather patterns on Earth. However, the physical processes by which the sun affects the weather have not been elucidated. And the precise data correlating sunspot maximums and minimums and weather on Earth go back only to 1952.

Many diaries and other written records indicate that the sun had very few sunspots from 1645 to 1715. Because these were the coldest years of the Little Ice Age and radiation seems to decline slightly today when sunspot activity is minimal, some climatologists believe declines in solar radiation were partly responsible for the Little Ice Age.

big difference in the results in local areas. Atmospheric models are notoriously imprecise in mapping the locations of effects. That doesn't indict the models' ability to predict that certain overall effects will occur. But models may never be able to pinpoint where the effects will happen. In other words, there may be an element of unpredictability in atmospheric behavior that will always make it impossible to project effects in a particular region.

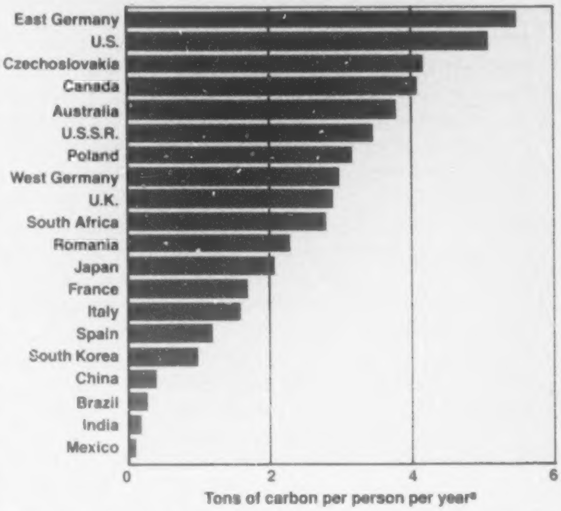
"In weather prediction, because of the physical properties of the atmosphere, very small changes in original conditions can lead to totally dissimilar scenarios after about a month," says Francis P. Bretherton, director of the Space Science & Engineering Center at the University of Wisconsin, Madison. "Systems we are not modeling in the general circulation models, such as terrestrial ecosystems, have a substantial influence on the balance of carbon and other greenhouse gases. They may turn out to be unpredictable over decades to centuries," he continues.

Effects of warming

If predicting temperature changes using climate models is difficult, predicting effects of global warming on natural ecosystems, water supplies, agriculture, and sea level is even more daunting. Models are not capable of reproducing regional temperature and precipitation for today's climate; their utility for projecting future changes in regional climates is even more questionable. Nonetheless, a number of efforts over the past few years, some of which rely on models, have been made to study the regional effects of global warming.

Sea level rise is potentially one of the more severe outcomes of global warming. Modelers project that sea level is most likely to rise 0.5 to 1.5 meters in the next 50 to 100 years, assuming no breakup of the West Antarctic ice sheet. The rise will come from thermal expansion of ocean water and from melting of mountain glaciers. The ice cap on East Antarctica is not expected to melt in the foreseeable future, but scientists believe the West Antarctic ice sheet, which is partially in contact with ocean water, may break up and melt, causing sea level to rise much more than 1.5 meters. Recent ocean-core data suggest, however, that this ice sheet has maintained its integrity for several million years.

Per capita CO_2 emissions in developed countries dwarf those in developing ones



a 1986 values. Measured as tons of carbon in carbon dioxide emissions from fossil fuel burning. **Source:** Oak Ridge National Laboratory

Higher sea level would increase the frequency and severity of flooding and damage to coastal structures, destroy wetlands, and cause saltwater intrusion into rivers and water supplies near the ocean.

One third of the world's population lives in low-lying coastal areas. A large part of the population of some countries is at risk if sea level rises substantially. For instance, half the population of Bangladesh lives at elevations of less than 5 meters. Bangladesh is already experiencing major flooding from a combination of subsidence and sea level rise. John D. Milliman of Woods Hole Oceanographic Institution has calcu-

Sea level rise so far has not accelerated

Though projections of future rises in sea level are sobering, so far there is no clear evidence that sea level rise is accelerating. During the past century, the global rise was 1 cm per decade. Sea level is higher along most coastlines worldwide, but in some places it has fallen. According to Tim P. Barnett of Scripps Institution of Oceanography, the increase in sea level each decade is only slightly greater than the margin of error in the instruments used to measure it, but sea level has shown a definite rise in the past 80 years. No measurements are being made of sea level in many parts of the world.

Besides global warming and the retreat of glaciers since the end of the Little Ice Age in the mid-19th century, other factors could affect relative sea level along the continental margins. Changes in the rate of tectonic movement of an individual plate along the continental margins can affect the relative tilt of a continent's coast and thus its relation to sea level. Continental margins also are constantly adjusting to loading and unloading events from ice sheets and sediments, but the total response of the continental plates lags by millenia the changes in imposed load. Thus, localized adjustments in sea level continue long after the triggering event. To obtain a more precise idea of what is happening to sea level, better measurements of continental uplift and subsidence and of changes taking place on the seafloor are needed.

Integration of federal research on global change sought

The federal government's research on global climate change currently resides in several agencies. Over the past eight months, a new federal interagency group, the Committee on Earth Sciences (CES), has spearheaded an effort to create a unified, integrated research program called the U.S. Global Change Research Program. CES is a bureaucratic offspring of the Federal Coordinating Council for Science, Engineering & Technology, which is a part of the White House Office of Science & Technology Policy.

CES and the Office of Management & Budget surveyed federal agencies' spending during the current fiscal year for research on global change in such areas as desertification, drought, volcanism, and global warming and developed a combined budget request for fiscal year 1990. In this process, special emphasis was put on global climate change.

CES has defined four major questions that form the core of the research agenda for the U.S. Global Change Research Program:

- What forces initiate global change?
- How does Earth's system respond to changes in forcing functions? (These responses or "feedbacks" include interactions among the climate, ocean, land, biota, and atmosphere.)
- How has Earth's environment changed in the past?
- How well can global change be predicted?

CES put current research efforts on global change into seven categories with a variety of budget levels. In addition to focused research, indicated by these dollars, the federal agencies are also funding other research that is linked with global change but was initiated for other primary purposes, such as weather forecasting, acid deposition, and remote monitoring. This related research forms a scientific base upon which global change research builds, and total funding for it may be as much as five to 10 times larger than funding for the focused research.

Federal funds for research on global change to jump 42%

$ Millions	1989	1990
Biogeochemical dynamics	$ 30	$ 45
Ecological systems and dynamics	28	40
Climate and hydrological systems	38	59
Human interactions	22	22
Earth system history	3	7
Solid earth processes	9	10
Solar influence	4	7
TOTAL	**$134**	**$190**

Note: Because the detailed definition of these categories changed during this process and may still be changing, the budget numbers may not accurately reflect the actual level of work within each category as it is now defined. Figures show budget appropriations for 1989 and funding requested for 1990.

At this time, the precise role that CES will play in determining the shape of the federal research program on global change has not been defined. Although few research managers apparently wish to repeat the troubled experience of the National Acid Precipitation Assessment Program (which saw a great deal of contention and rivalry among the member agencies), the need for a collegial forum for developing research strategies and general research plans is widely acknowledged. Moreover, CES is envisioned to be the mechanism for coordinating the U.S. science community's involvement in the International Council of Scientific Unions' emerging International Geosphere-Biosphere Program. In that role, it could help establish flexible structures for facilitating the international flow of information among members of the research community and affected governments.

The International Geosphere-Biosphere Program is a plan for international cooperation in research on global change. The plan, which is scheduled to begin in the early 1990s, will be coordinated by the International Council of Scientific Unions, an organization of scientific royal societies and national academies from around the world.

lated that if present trends continue, Bangladesh will lose up to 18% of its habitable land by 2050. He also projects that a combination of sea level rise and loss of soil replenishment on the Nile delta because of upstream damming will destroy as much as 19% of Egypt's arable land. Other areas at great risk include the Netherlands, the Maldives (a series of 1800 islands in the Indian Ocean that nowhere have an elevation higher than 2 meters), and the Pacific Islands of Kiribati, Tuvalu, and the Marshalls. Among the large cities in danger are New Orleans, New York, Miami, Galveston, Rotterdam, Venice, Bangkok, and Taipei.

Developed countries may be able, at least for a number of years, to protect their cities from the sea by building bulkheads, levees, and dikes. But in the Netherlands, experts expect that if the sea level rises a meter or more, large areas of the country will have to be flooded with fresh water to prevent saltwater intrusion. And most developing countries will not be able to afford the billion-dollar expenditures required to construct bulkheads and levees.

A less dramatic result of rapid sea level rise is flooding of wetlands. A 1988 assessment prepared by the Environmental Protection Agency projects that if sea level rises 1 meter, 26 to 65% of the wetlands in the U.S. will be lost. But if efforts are made to protect coastal structures with bulkheads and levees, 50 to 82% of the wetlands could be destroyed because the bulkheads and levees that are necessary to defend buildings also keep the sea from moving inland and creating new wetlands. Thus it may not be possible to protect both coastal structures and wetlands. Furthermore, in some heavily developed coastal areas that are largely covered with concrete and buildings, the sea cannot move in and create new wetlands because there is no undeveloped land.

In cities like Miami, which is built on reclaimed coastal marshland where the water supply is only 3 feet below the surface, a rising sea will intrude into water supplies.

Some natural ecosystems are also at great risk from rapid regional climate changes. In the Northern Hemisphere, the ranges of particular tree species are likely to be reduced because trees in the southern part of the present range may die off much more quickly than trees can propagate above the northern boundary of the range. Margaret B. Davis and Catherine Zabinski, ecologists at the University of Minnesota, studied how fast U.S. eastern hemlock, yellow birch, beech, and sugar maple would have to migrate in the next century with temperature changes predicted by two widely used climate models. Under conditions projected by both models, the ranges of all four trees would have to shift 500 to 1000 km, and, in the process, would be reduced drastically. According to one of the models, sugar maple would die out throughout the U.S. except in Maine. Similarly, a recent EPA report that draws on studies for a number of species across the country predicts that large forest areas in the U.S. would change to savannah or grassy plain, causing a loss in forest productivity.

Davis points out that a number of uncertainties plague these projections. For instance, it is not known whether the particular ecotype or subspecies that now lives in one range will be able grow in the different light and soil conditions of a more northerly range. It may be that without massive human intervention, some species would die out completely.

Although the outlook is poor for canopy trees, it is even worse for understory plants, such as shrubs and wildflowers. Many of them are propagated by the wind scattering relatively few seeds. The chances of the wind blowing their seeds to suitable habitats is minimal, Davis says.

The effects of global warming on managed forests are somewhat easier to counteract than those on wild forests. In theory, seedlings can be developed that are hardy enough to withstand increased heat and possibly reduced precipitation. But forest managers will have to be aware and have enough information to know what the climate will be like over the next 30 years until the trees are harvested. Overall, analysts expect U.S. forestry to experience a net loss from global warming.

Benefits and problems

The regional effects of greenhouse-induced climate change on agriculture could be either positive or negative. Global warming likely would affect agriculture through changes in the length of the growing season and the frequency and intensity of heat waves and rainfall. But not enough is known about the regional effects of global warming and of plants' response to a warmer world to define the net results.

Some plants, fertilized by higher levels of carbon dioxide, will grow faster. High carbon dioxide levels also induce some plants to use water more efficiently. But crops that are fertilized with excess carbon dioxide may be more vulnerable to pests and diseases. Also, weeds on the whole are more likely to benefit from fertilization by carbon dioxide than are crop plants.

Rising global temperatures also will shift the crop-growing regions from south to north in the Northern Hemisphere. The 1988 EPA effects report projects that "Crop acreage in Appalachia, the Southeast, and the southern Great Plains could decrease by 5 to 25% and acreage in the northern Great Lakes states, the northern Great Plains, and the Pacific Northwest could increase by 5 to 17%." It also predicts that with warmer temperatures, farmers would rely much more on irrigation to combat heat stress. The productivity of farming regions depends to a large extent on the amount of precipitation. The models EPA used differ greatly in their projections of the amounts of rainfall for various regions, causing the predicted productivity of the regions to differ greatly.

If food-growing acreage remains the same, but moves north, productivity would not necessarily remain the same. If soil quality is poorer in the new, more northerly crop-growing regions, the same amount of acreage would grow less food. The U.S. Midwest is now highly productive because of an extraordinarily favorable combination of soil, temperature, and moisture.

Chip Stem of Tufts University veterinary school says that global warming could expand the northern range of livestock diseases and pests in the U.S. and create favorable conditions for the introduction of new diseases. "Many animal diseases are kept in check largely because of the restriction climate places on the disease-carrying organisms, the environmental habitats, and the disease-causing agents themselves," says Stem.

Experts also project that global warming will have a net adverse effect on water supplies. In this area, the predictions are highly uncertain because they depend on where and how much precipitation falls—the most uncertain aspects of the general circulation models.

However, analysts say that much more water will be required for irrigation to combat the effects of heat stress. And they project that the most vulnerable water supplies are those that depend on the slow melting of snowpack in the mountains for water during the spring and summer. Most of California's water supplies are in that category. If the snow that now accumulates on California's mountains falls as rain or melts quickly during the winter, the water supply for California in the summer will be severely depleted.

EPA warns that given the uncertain effects of global warming on water supplies, "Water resource managers should consider ways to improve the flexibility and efficiency of water management systems to handle climate change and variability."

Tie-in strategies

Scientists and policymakers respond to uncertain predictions of global warming in basically three ways. Some say that the warming projected by even the most conservative models is so severe that fast action is necessary now to reduce its impact on the atmosphere. This should be done as a kind of insurance to delay or prevent the potentially devastating effects of global warming, just as people routinely take out insurance to protect themselves from other kinds of disasters that can be predicted only in terms of probabilities. Those who favor immediate preventive action point to the uncertainties involved in the greenhouse effect as a further reason for their view. Because of the unknowns, global warming and its effects could be far more severe or rapid than any models predict, they say.

Others believe that reducing or curtailing emissions of greenhouse gases is so difficult and involves so many activities that are basic to human life, such as heating homes and growing rice, that global warming will be nearly impossible to prevent or even slow down. They advocate adaptation to the warming. Mankind should plan for and learn to live in a warmer world.

Still others hold that there are so many uncertainties involved in global warming that scientists cannot possibly predict what the consequences will be. Humanity should therefore not invest time or money to reduce emissions of greenhouse gases until the problem is better understood, this group contends.

Until recently, most scientists and policymakers advocated adaptation or research-only strategies. Now that a number of modelers believe that there will be very clear signals of greenhouse warming in the 1990s, many view the situation differently. They favor some combination of emission reductions to slow the warming and adaptation to a certain amount of inevitable warming they expect from greenhouse gases that are already in the atmosphere.

There is no single scientifically correct view of what should be done about greenhouse warming. This is a value question involving perceptions of risk and uncertainty.

One approach advocated by many policymakers, scientists, and environmentalists is to use tie-in strategies—to take action that is beneficial in its own right even if no greenhouse warming occurs. Several of the strategies proposed are to reduce deforestation in the tropics (in part by relieving poverty), increase energy efficiency, stop production of CFCs and cut production of other halocarbon greenhouse gases, develop renewable alternatives to fossil fuels, and stabilize world population.

Reducing deforestation in the tropics is valuable even without global warming because it would help preserve the rich abundance of species in the tropics and stop some of the negative climate and resource changes that result from deforestation itself. Often deforestation causes higher temperatures and drought and creates land that will not support crops for more than a few years.

The more efficient use and production of energy—by using more efficient factories, for example, or raising mileage standards on automobiles—is also beneficial in its own right.

Halting and cutting back the production of CFCs and other halocarbons would help prevent stratospheric ozone loss. And switching to greater use of renewable fuels would reduce emissions of sulfur dioxide and nitrogen oxides that cause acid rain as well as help prepare the economy for a time when oil and gas will be in very short supply globally.

Stabilizing the world's population, which, according to the Population Reference Bureau, is now increasing at a rate of 87 million people per year, is essential to stabilizing the atmospheric burden of greenhouse gases. It could also help in creating better living conditions in many parts of the world and in allowing agricultural production to catch up with population.

About 40 countries are now involved in a United Nations-sponsored effort to develop cooperative mitigation strategies for global warming. A meeting in Washington, D.C., in January was the first in a number that will be held to formulate such strategies. Eventually, these negotiations may lead to a law of the air or a convention for protection of the atmosphere. Last June, at the conference on the Changing Atmosphere in Toronto, Gro Harlem Brundtland, Prime Minister of Norway, proposed "a global convention on protection of the climate."

Cutting emissions of greenhouse gases to slow or lessen global warming is extremely difficult. One of the major problems is that the per capita emissions of carbon dioxide in the developed countries are far greater than those in the developing countries. For example, the annual emissions of carbon dioxide (weighed as carbon) is 5 tons for every man, woman, and child in the U.S., compared with only about 0.1 to 0.4 ton in China and India. To develop economically, China and India will be forced to increase their emissions substantially. If China meets its goal of raising its per capita gross national product to only 15% of the U.S. figure, the increase in carbon dioxide emissions in China would about equal current emissions from all the coal consumed in the U.S. Similarly, if India maintains its current per capita emissions, its projected population growth will cause an increase in emissions by the middle of the next century equal to the current U.S. total from coal.

This means that even very drastic steps to cut back or eliminate carbon dioxide emissions in the U.S. will not reduce worldwide emissions if the populous developing countries succeed in raising their living standards to even a fraction of the U.S. level or if population growth does not stop. It underscores the need to develop international approaches to global warming because a few countries can't solve the problem alone.

Doing something about global warming will be extremely difficult, but perhaps not so difficult or expensive as doing nothing. Jaromir Nemec, chief of water resources for the Food & Agriculture Organization of the United Nations said last year: "The risk is too large not to look for possible alternatives and means of mitigation even if the search is based on predictions with a large margin of error. Forecasting is a dangerous game. Blind and passive waiting for a possible disaster is even more dangerous." ◻

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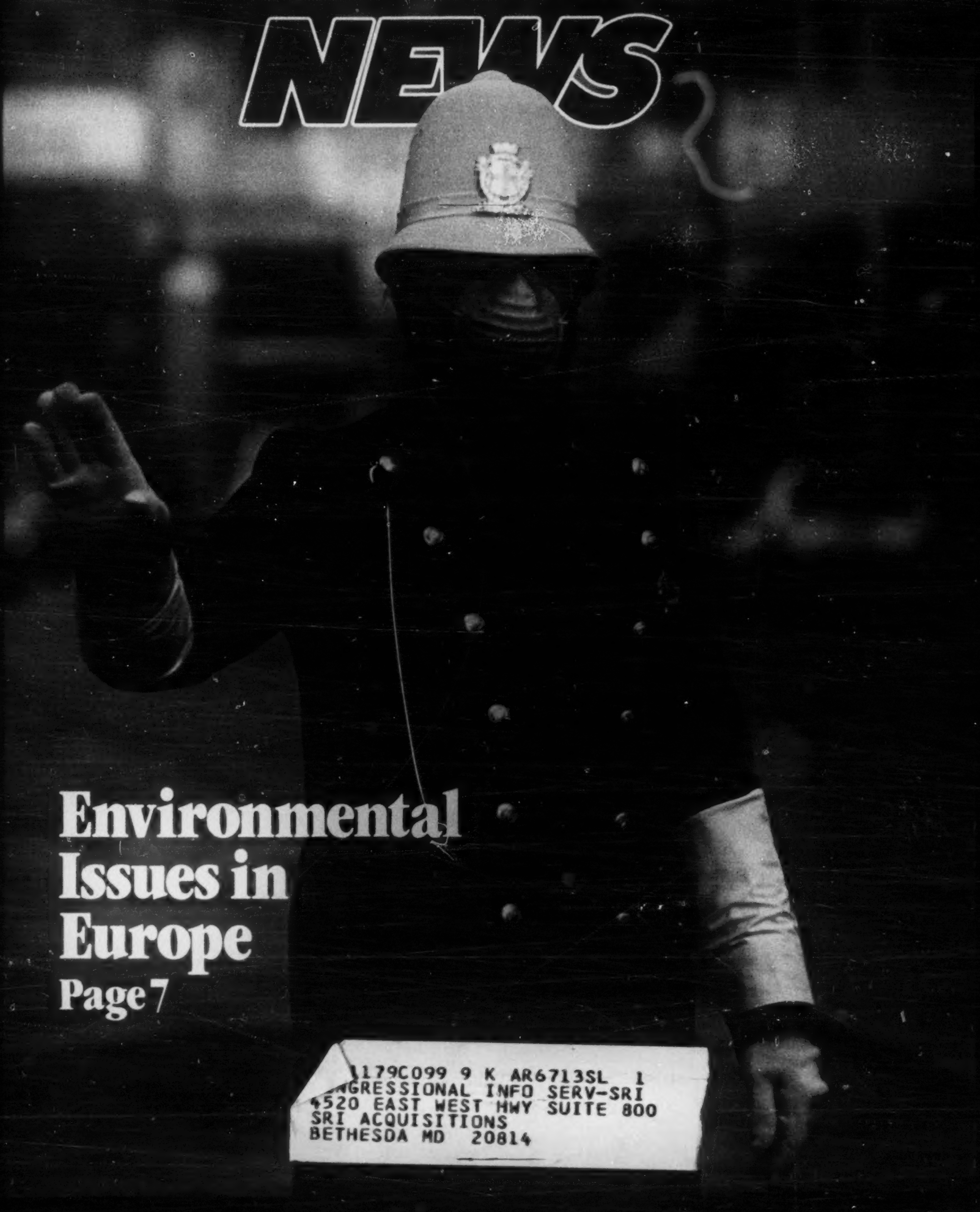

Environmental Issues in Europe

Page 7

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News of the Week

■ **French oil and chemical producer Elf Aquitaine has signed a $1 billion agreement for acquisition of Philadelphia-based chemical company Pennwalt.** Page 4

■ **NASA makes plans for "Mission to Planet Earth," an observation system that will monitor changes in the global environment.** Page 5

■ **Foreign firms and inventors last year won close to half the patents awarded by the U.S.** Page 5

■ **Noted chemist Max Tishler, who spent his life applying chemistry to fight disease, died this month in Connecticut.** Page 6

■ **Symposium held to celebrate new affiliate for Beckman Center for the History of Chemistry generates debate on human genome project.** Page 6

Business

Internationalization, high-tech chemicals, and environmental issues forecast to dominate chemical industry for next decade. **Page 18**

Government

EPA report provides nations with policy options to limit greenhouse emissions, protect Earth's climate. **Page 22**

Sales of chemical arms production equipment to Egypt, Iran by Swiss firm worry Bush Administration. **Page 23**

Consumer Product Safety Commission seeks Congressional support, more funds in order to remain active. **Page 24**

Science/Technology

Innovations in dynamic fluorescence spectroscopy promise to renew interest in fluorometry as analytical tool. **Page 27**

Research on lignin-degrading enzymes makes major contribution toward understanding biodegradation of lignin. **Page 29**

Books

"Lowrys' Handbook of Right-To-Know & Emergency Planning" reduces complex, legalistic regulations to a simple descriptive format. **Page 30**

Cover: Traffic policeman in Milan wears mask to protect against air pollution. Photo by Pierre Schwartz/Sipa Press

Letters 2

Concentrates
Business 16
Government 21
Science/Technology 26

The Departments
ACS News 33
Awards 35
Meetings 37
Newscripts 48

News Focus

Growing concern in Europe over pollution problems and how to deal with them has made the environment a major factor in policy and trade decisions. **Page 7**

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LETTERS

Chemical weapons

SIR: The editor of C&EN has correctly pointed out (C&EN, Jan. 16, page 5) that as Vice President, George Bush had spoken in opposition to chemical weapons. At ongoing disarmament talks in Geneva in 1984, he presented a draft treaty that would halt production of chemical weapons. And as President-elect, he had publicly stated that he would like to be the President who was instrumental in ridding the world of chemical and biological weapons. These are indeed welcome words.

We can only hope that with President Bush words will speak louder than actions. On three occasions, when there was a tie vote in the Senate on nerve gases or nerve gas weapons, Vice President Bush cast his vote in favor of the nerve gases. These votes occurred on July 3, 1983; Nov. 8, 1983; and Aug. 7, 1986. Unfortunately, a healthy skepticism is in order.

Thomas Rees
Hamden, Conn.

Portable pensions

SIR: With regard to Attila Pavlath's report on the desirability of portable pensions (C&EN, Dec. 19, 1988, page 45) and Gabriele Wohlauer's excellent letter (C&EN, Jan. 30, page 3), I would like to call attention to another method besides layoffs by which pensions have been drastically reduced without any action or recourse by the employees.

In 1955, I went to work for General Electric at a major Atomic Energy Commission laboratory. A few months short of 10 years later (at that time the GE pension was 0% vested before 10 years), AEC replaced GE as the prime contractor operating the laboratory. Except for less than a half-dozen top managers and administrators, the staff remained the same and became employees of the new contractor. Continuity of service was maintained with regard to vacation and some other relatively minor benefits but not with regard to pension. In my own case, this change of AEC prime contractors did not in any way affect the program I was working on or where I worked (I have had the same laboratory in the same building for 33 years); nor did it change who I reported to for at least two levels of management above me. I was paid a small cash value for my nonvested GE pension, which I immediately rolled over into an annuity set up by AEC for that purpose. As I approach my planned retirement date, it has become clear that my total pension, including the small annuity based on my GE years, will not exceed 70% of what it would have been if one contractor had operated the laboratory for the entire time.

AEC, followed by the Energy Research & Development Administration and later yet by the Department of Energy, has changed contractors at various of their sites, and at some sites several times. It is my understanding that, at least in part of these prime contractor changes, pensions have been better dealt with. I have been told that in the contractor change affecting my pension it was the new contractor who insisted on the arrangement made, but I do not have firm information to either confirm or refute that. Employers have opposed portability of pensions to discourage employees from changing jobs. Although one may or may not agree with that attitude, one can see that it is a valid issue. On the other hand, it is hard to see any valid arguments whatsoever for not fully protecting pensions of those loyal employees caught by involuntary layoffs or by laboratory contractor changes. I feel that ACS and other professional and labor organizations should take a strong stand in whatever ways they can to help to get this situation corrected.

Jack L. Ryan
Richland, Wash.

Fluoridation of water

SIR: Surgeon General C. Everett Koop has asserted there is "no credible evidence of harm that would justify abandonment of fluoridation" (C&EN, Nov. 28, 1988, page 2). Just what kind of evidence he would find convincing is not clear, but he certainly did not offer any scientific grounds to reject unrefuted published findings of clinically demonstrated adverse health effects from fluoridated drinking water, as reported by Bette Hileman in her article on fluoridation (C&EN, Aug. 1, 1988, page 26).

My late husband, George L. Waldbott, M.D., who was nationally and internationally recognized for his extensive research on allergic-type hypersensitivities, devoted more than 25 years to the investigation of toxic effects of fluoride. He proved unequivocally, and other physicians have fully confirmed his findings, that fluoride added to drinking water at the officially recommended concentration of 1 ppm causes serious poisoning in sensitive individuals. In certain instances he conducted blind and even double-blind tests as recom-

NASA makes plans for Earth surveillance

The Earth Observing System (EOS), an ambitious project to monitor global changes in Earth's environment through satellite-based instruments, moved one step closer to reality last week. Some 200 scientists met at the National Aeronautics & Space Administration's Goddard Space Flight Center in Greenbelt, Md., to do some detailed planning for what NASA administrators are describing as "potentially the largest scientific undertaking in the history of spaceflight."

The EOS measurements, which will be taken from platforms circling the globe in polar orbit, are the first part of an even larger program laid out by NASA as "Mission to Planet Earth." The goal of the program is to understand Earth as an integrated system by simultaneously observing the atmosphere, oceans, and land. Scientists will then be able to come up with quantitative predictions for policymakers trying to deal with global change.

"Problems with broad global impact, such as ozone depletion and greenhouse warming, cut across disciplines," says NASA EOS scientist Dixon M. Butler. "Space has a unique role to play in global projects."

Despite its ultimate price tag of $15 billion to $30 billion over 15 years, Mission to Planet Earth has strong Congressional support. Both Sen. Ernest F. Hollings (D.-S.C.), chairman of the Committee on Commerce, Science & Transportation, and Sen. Albert Gore Jr. (D.-Tenn.), chairman of the subcommittee that oversees space programs said in a recent hearing that the program should be a top NASA priority.

Some observers are concerned, however, because current funding for such global observations is tied to the controversial manned space station. Specifically, money for the first EOS polar platform has been allocated under the space-station program, even though the satellite will have no physical or logistical connection to the station. The fear is that the more glamorous manned program could shoulder out the more cost-effective satellite research program. "When the National Research Council reviewed the space-station program about a year and a half ago, it said there is no natural link between the manned base and the satellites and that each should be considered on its own merits," points out Marcia Smith, aerospace policy specialist with the Congressional Research Service.

For now, however, the hardware for the first EOS polar platform is being developed by NASA's office of the space station at an estimated cost of about $400 million with an anticipated launch date of 1996. NASA also plans to build a second polar platform, with two more to be built by the European Space Agency and one by the Japanese Space Development Agency.

Pamela Zurer

Foreigners win almost half of 1988 U.S. patents

Reaching a new peak in a steadily rising trend, foreign firms and inventors last year won close to half the patents awarded by the U.S., according to figures just released by the Patent & Trademark Office.

Of 84,272 patents issued last year, 39,702 or 47.1% went to foreign residents—an increase of 0.5% over the 46.6% foreign portion in 1987 (C&EN, March 7, 1988, page 7). The foreign share is well over double 25 years ago, going from 18.6% in 1963 to 36.7% in 1978 and 45.4% in 1986.

Japan leads foreign countries by far, with 16,984 patents (20.2% of the overall total), up from 19.3% in 1987 and 18.0% in 1986. Its share has doubled in a decade from 10.1% in 1978. Japan replaced West Germany in 1975 as the foreign leader.

West Germany ranks second, with 7501 patents (8.9%). France and the U.K. come next, both with 3.3%. Making its first appearance among the top 10 foreign nations is Taiwan, with 536 patents (0.6%). Its U.S. patents have soared from just 40 (0.06%) in 1978 to 165 (0.2%) in 1985, 269 (0.3%) in 1986, and 411 (0.5%) in 1987. China won only 48 patents in 1988; the U.S.S.R. had 97.

Five of the top 10 firms winning patents in 1988 are Japanese: Hitachi (1), Toshiba (3), Canon (4), Fuji (5), and Mitsubishi (9). West Germany's Siemens (7) and Bayer (10) and Dutch-owned North American Philips Corp. (6) rank high. General Electric/RCA (2) and IBM (8) are the only U.S.-owned firms on the list.

Figures have not beem compiled for the foreign share of U.S chemically related patents, according to the Chemical Manufacturers Association and other sources. However, the Pharmaceutical Manufacturers Association finds that, similar to the overall trend, foreigners have won about half of U.S. patents on drugs and medicines during the past decade. Japan leads all foreign nations here, too.

The U.S. still has a big lead in biotechnology, however, PMA finds. For example, in 1987 U.S. inventors won 80% of the 199 patents for pharmaceutical and health care products based on genetic engineering.

The latest PTO figures are likely to increase concern over U.S. technological competitiveness. Indeed, PTO's assistant commissioner for patent examining, Rene D. Tegtmeyer, tells C&EN that U.S. firms have had a large, comfortable domestic market, and have been complacent. They have de-emphasized R&D, and neglected to protect themselves with patents.

However, he adds, "In recent years, they've been getting a rude

Japan far in lead in gaining U.S. patents

	1988	% 1988	1987
Japan	16,984	20.2%	17,288
West Germany	7,501	8.9	8,030
France	2,792	3.3	2,990
U.K.	2,756	3.3	2,967
Canada	1,642	1.9	1,769
Switzerland	1,298	1.5	1,440
Italy	1,172	1.4	1,285
Netherlands	899	1.1	997
Sweden	891	1.1	1,089
Taiwan	536	0.6	411
Other foreign countries	3,231	3.8	3,408
TOTAL TO FOREIGNERS	39,702	47.1%	41,674
TOTAL ISSUED	84,272	100%	89,385

Source: U.S. Patent & Trademark Office

awakening." Patent applications in the 1980s by U.S. inventors have grown in absolute numbers, although not so fast as foreign filings. Moreover, he now sees signs that things may be turning around. In fiscal 1988, for the first time in many years, the U.S. share of patent applications rose, up to 54.9% from 54.6% in fiscal 1987. The U.S. share hit 55.3% in the first quarter of fiscal 1989, continuing the trend. These are small changes requiring further confirmation, and they will take about 18 months to affect patent issuance figures. But Tegtmeyer considers them "very promising."

Richard Seltzer

Max Tishler, drug pioneer, dead at 82

Max Tishler, 82, who spent his life applying chemistry to fight disease, died of emphysema on March 18 in Middletown, Conn. He was cited in 1987 as "a giant on the chemical scene" when he was awarded the National Medal of Science, the nation's highest scientific honor.

As the former head of Merck Sharp & Dohme Research Laboratories in Rahway, N.J., Tishler led research programs that developed drugs or vaccines for heart disease, hypertension, arthritis, mental depression, and infectious diseases, as well as products to control poultry and livestock diseases.

He led the Merck team that developed a production process for penicillin during World War II, and played a key role in developing processes for vitamins B_2, B_6, K_1 and E; pantothenic acid; biocytin; and nicotinic acid. He helped launch a new era in treatment of inflammatory disease through a process for large-scale production of cortisone.

After 33 years at Merck, Tishler made perhaps the most difficult decision of his life: Eighteen months short of the mandatory retirement age of 65, he accepted a research and teaching post in 1970 at Wesleyan University in Middletown. "I am simply not ready or willing to retire," he said.

Shortly after beginning his "second career" at Wesleyan, Tishler received the American Chemical Society's highest honor, the Priestley Medal. He served as ACS president in 1972.

He later became a university professor emeritus at Wesleyan, where he continued his research on bioactive compounds and got students interested in the field. Peter S. Wharton, an organic chemistry professor at the university, says Tishler "made a tremendous impact on Wesleyan. He brought life and activity to this place."

During his half century at Merck and Wesleyan, Tishler published more than 100 papers and was granted well over 100 U.S. patents. He said he decided to devote his life to relieving the sufferings of the sick when, as an errand boy for a neighborhood pharmacy in his native Boston, he witnessed the ravages of the 1918 flu epidemic.

He received his B.S. degree in chemistry from Tufts University in 1928 and a Ph.D. in organic chemistry from Harvard University in 1934. After three years of working as a research associate and instructor at Harvard, he joined Merck as a bench chemist. He rose rapidly at Merck, serving as a research director, vice president and executive director, president, and finally senior vice president for R&D in 1969.

Ron Dagani

Debate swirls around human genome project

Debate centered on the project to map the human genome as scientists met last week at a symposium in Philadelphia, "The Merging of Chemistry and Biology: Looking Backward/Looking Forward."

The symposium celebrated affiliation of the American Society for Biochemistry & Molecular Biology with the Arnold & Mabel Beckman Center for the History of Chemistry. The center is a joint endeavor of the American Chemical Society, American Institute of Chemical Engineers, and University of Pennsylvania, with the Chemists' Club and the Electrochemical Society also being affiliates.

The project to map the human genome is a "political football" that "has been sold to the public as a phony bill of goods," said Nobel Laureate Joshua Lederberg, president of Rockefeller University. Proponents of the project to sequence the 4 billion base pairs of DNA in human chromosomes argue that the knowledge will reveal all aspects of body structure and function, he says. But the opposite is the case. Scientists will have to analyze human biological functions to understand the DNA sequence. Lederberg predicts that when the public realizes this, there will be "disillusionment" and "a possible backlash."

But biochemistry professor Paul Berg of Stanford University, also a Nobel Laureate, is more optimistic. He notes that the project will begin efficiently by mapping the genome to provide signposts for the later sequencing. This genetic map, which could be ready in two years, will be followed by a physical map to locate certain DNA sequences on chromosomes known to bear genes related to human disease.

Berg says that the complete sequence, when determined, will not be recognizable except where it is most obvious. Biologists will still not know how it all works. Berg suggests that help might come from computer scientists, experienced as they are in logical symbol manipulation and pattern recognition.

Stephen Stinson

Environmental Concerns Gain Prominence in Europe

With flurry of diverse issues ranging from dumping of industrial wastes in landfills to the buildup of noxious gases in urban air, environmental problems have become major factor in policy and trade decisions

Dermot A. O'Sullivan, C&EN London

The Mayor: The point at issue is not a purely scientific one; it is a complex question, with both technical and economic aspects.

Dr. Stockmann: But the source is poisoned, man. Are you mad? We live by trafficking in filth and corruption! The whole life of our flourishing community is founded on a lie!

From "A Public Enemy"

When Norwegian dramatist Henrik Ibsen penned these lines more than 100 years ago in his play that centers on an environmental theme, he unknowingly foreshadowed some of the keen concerns that currently flourish throughout Europe. Hardly a day passes without some mention in the media about such diverse issues as the dumping of municipal and industrial waste in landfills, accidental spillages into major waterways, pollution of bathing beaches by raw sewage effluent, and buildup of noxious gases in urban air reflecting the growing use of automobiles.

Just a few weeks ago, for instance, smog built up in Paris to the point where the stately Eiffel Tower was half hidden from view. And conditions were so bad in Milan that traffic police took to wearing masks.

The problem stemmed from the unusually mild winter throughout much of Western Europe, coupled with an inversion layer that trapped exhaust fumes at ground level. Milan's mayor, Paolo Pillitieri, urged restraint in the use of cars and home heaters. And vehicles without special permits were banned from the city center.

At one point, readings of 431 μg per square meter of sulfur dioxide, and 423 μg per sq m of nitrogen dioxide were recorded in central Milan. The figures far exceed the maximum levels recommended by the environment directorate of the European Community: 250 μg per sq m for sulfur dioxide and 200 μg per sq m for nitrogen dioxide.

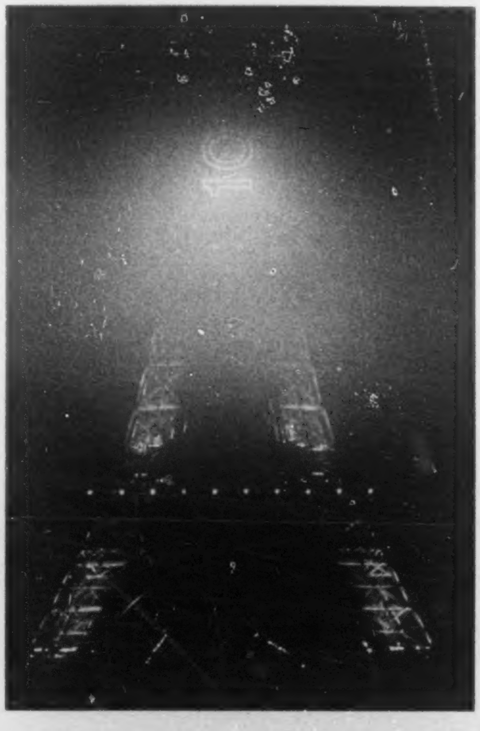


Photo by Pierre Schwartz, Sipa Press

Many international events with environmental themes are being staged in Western Europe. In the opening days of this month was a conference in London titled "Saving the Ozone Layer." Organized at the behest of U.K. Prime Minister Margaret Thatcher, and cohosted by the United Nations Environment Program (UNEP), it served to focus the attention of some 700 senior delegates from 124 countries on the urgency of reducing, and eventually eliminating, use of ozone-depleting chlorofluorocarbons (CFCs) and halons.

In The Hague a few days later, the prime ministers of France, the Netherlands, and Norway jointly held a meeting attended by leaders of 24 countries. They signed a "declaration" promoting five "principles." One urges creation of a "new institutional authority within the framework of the United Nations which shall be responsible for combating further global warming of the atmosphere." Another calls for "appropriate measures to promote the effective implementation of, and compliance with, decisions of the new authority, which will be subject to control by the International Court of Justice [in The Hague]."

As C&EN was going to press, ministers and high government officials from more than 100 countries were meeting in Basel. They were seeking final agreement on a treaty, drawn up with the help of UNEP, to limit and control international transport and disposal of hazardous waste. And in Helsinki in early May there will be a meeting of signatories of the 1987 Montreal protocol that calls for cuts in output of CFCs and halons.

Even royalty is getting in on the environmental act. Queen Beatrix of the Netherlands devoted her entire annual Christmas speech last year to the subject. "It is encouraging to see people and nations everywhere calling each other and themselves to order," she said. "We face the challenge of finding a new relationship with nature, marked by regard for ecological equilibrium, circumspection, and careful management. We are duty bound to leave our habitat in at least as good a condition as we found it. The quality of life itself transcends the interests that matter in our own temporary lives."

Likewise, the U.K.'s Queen Elizabeth II noted in her annual Commonwealth Day message this month that "Concern for the resources we share in common means partnership not only across oceans, but also between generations." And her son, Prince Charles, in a no-nonsense address to those who attended the ozone-saving conference, observed that "The seas are fast becoming sewers. We make poisons so powerful we don't know where to put them. Rain forests are being turned into deserts. If we can stop the sky turning into a microwave oven, we still face the prospect of living in a garbage dump."

Thatcher caused some raised eyebrows at her after-dinner talk last fall to the Royal Society in London in which she devoted a considerable portion to environmental issues. Noting specifically the greenhouse effect, the hole in the Antarctic ozone layer, and acid rain, she said, "In the past, when we have identified forms of pollution, we have shown our capacity to act effectively. Even though this kind of action may cost a lot, I believe it to be money well and necessarily spent, because the health of the economy and the health of the environment are totally dependent upon each other."

Media pundits and environmentalists, referring to what they see as "The greening of Mrs. T," make the point that during her 10 years in office, her government's record on environmental issues leaves much to be desired. Indeed, Britain's all-party Environment Committee attached to the House of Commons takes the U.K. to task in a just-published, strongly worded report dealing with municipal and industrial waste.

Referring to dumps and landfill sites throughout the country, Sir Hugh Rossi, who chairs the committee, says: "No one knows what's in them. God knows what kind of time bomb we are sitting on. It is little short of a miracle that we have not had disasters from the escape of poisons into our water supplies, or from gas explosions, although we have come perilously close to it."

The treatment and safe disposal of waste, both solid and liquid, is big business in Europe. Each year, about 2 billion tons of waste of all kinds are generated by the 12 member countries of the European Community alone. Industrial waste in those countries accounts for an estimated 160 million tons, of which up to 30 million tons is classed as toxic or dangerous. Most of this problem waste comes from the chemical industry. Its handling entails considerable technical expertise.

C&EN staff photos

Jourdan (above): pollution prevention pays. Klatte: group condemns burning of waste in North Sea

Waste associations of Belgium, France, West Germany, Italy, the Netherlands, Spain, and the U.K. now are linked through the European Federation of Special Waste Industries (CEADS). Corresponding bodies from other European countries may join following CEADS's first general assembly next month in Brussels.

Says CEADS executive director Rolf Eder at its Bonn headquarters: "Our members are active in all areas of waste treatment—incineration, distillation, recycling, recovery, and so on."

One of the organization's functions is to disseminate information pertinent to its members. For example, it provides a forum for discussion of new and improved techniques. Also, it keeps abreast of waste-related legislation in various countries, and of developments emerging from international bodies such as the Organization for Economic Cooperation & Development (OECD) and UNEP. It also provides a liaison with CEFIC, the European Chemical Industry Federation, although it is separate from it.

CEFIC's Louis Jourdan, the organization's director of technical affairs, points out that the federation has been closely involved for a number of years in the many aspects of environmental issues as they relate to the chemical industry. Responding to a widespread perception that waste, especially that coming from the chemical industry, is a threat to health and the environment, a 12-member CEFIC industrial waste management task force drawn from representatives of the leading European chemical companies meets regularly to maintain an overview of the situation and formulate codes of practice.

"Much play has been given to the 'Polluter Pays Principle' coined some years ago," Jourdan observes. "But it is equally true that the public pays for pollution, and that pollution prevention pays. This is the message I try to get across. The savings a company makes in running its operations cleanly and with the minimum of waste that must be disposed of can be passed on to the customer. The resulting lower-cost products will be favored in the marketplace over those of competitors."

What to do with the waste that does accumulate is a problem, nevertheless. Some goes for incineration out in the North Sea. But many condemn the practice because of the harm it may do to the marine environment. Ernst R. Klatte, who heads Greenpeace International's Brussels office, points to a position paper his group has drawn up claiming that more than 100,000 tons of waste is incinerated each year in the North Sea, over half of it coming from West Germany. "We are preparing now for the third North Sea Conference [a regular meeting of representatives from countries bordering the North Sea] planned for The Hague next year when this, and other issues, will be discussed at length," he notes. Acknowledging the concern, the U.N. International Maritime Organization based in London is taking steps that could lead to a ban on North Sea burning after 1994.

Some countries have resorted to shipping waste for dumping in developing countries, many on the west coast of Africa, that are ill equipped to cope with it. This caused something of an international furor last year when such cargos were found to have been surreptitiously off-loaded in Nigeria and elsewhere. Some European countries are legislating bans on such shipments. And the practice would be curtailed further if the UNEP-inspired treaty is adopted.

Several European countries operate collection systems for chemical waste from households and small industries. In the Netherlands, for example, specially designed Chemocar trucks move through communities at regular intervals to pick up and take away such products as paints, solvents, and motor oils for disposal in supervised facilities in much the same way that paper and glass are collected.

Denmark has had a chemical waste incineration program since 1975. The Kommunekemi treatment plant, operated under license from the National Agency of Environmental Protection, is sited at Nyborg on Funen Island. Two furnaces cope with about 100,000 metric tons annually of organic and oily waste. A third nearing completion will help in disposing of what is expected to reach some 150,000 metric tons per year.

Combustion and destruction efficiencies are extremely high, well above 99%, claims Albert S. Welinder of the environment protection agency. But he admits that the planning process for the new incinerator line "has been long and tedious, involving political decisions in the local council for more than a year, with the focus on factors of a psychological, rather than a physicochemical, nature. Clearly, further increases at Nyborg are not acceptable."

The 540 municipal incinerators throughout the EC dispose of about a quarter of the member countries' waste each year. Moves now are afoot that, if adopted, will standardize gaseous emission measuring systems, and set limits on the quantities of chemicals that may be released into the atmosphere. Those being considered include hydrochloric and hydrofluoric acids, dioxins and furans, sulfur dioxide, and heavy metals.

Although incineration plays an important role in the removal of waste, the plants and their operators are subject to frequent criticism and rebuke by those who happen to live near them. Any plans for expanding the system, or installing

In Netherlands, special trucks pick up paints, oils, other products for disposal new facilities, usually evoke strong opposition.

"Here, we get into the not-in-my-backyard, or NIMBY, syndrome," comments Edward Bennett, director of nuclear safety, waste management, and the prevention and control of chemical pollution at the EC's environment directorate in Brussels. "It is a problem for any high-tech plant for the treatment of waste. People say, 'We recognize the need, but put it somewhere else.' "

It was partly to sharpen people's awareness of the need for protecting their environment, and partly to publicize measures toward achieving this end, that the EC organized its European Year of the Environment, which ended March 20 last year. With considerable hype, member countries arranged shows and demonstrations, produced videos and reading material, planned guided walks in the countryside, held contests, and gave awards to "clean" industries. Chemical companies heartily endorsed the event and provided support to the programs.

The legal means of safeguarding the environment throughout the EC is by directives prepared by the 12-member council of environment ministers, drawn from each of the member states, following proposals from the EC Commission. When a directive is adopted, it goes through the parliamentary processes in each member country before it becomes an EC law. Parties that don't abide by the rules laid down could ultimately be brought before the European Court of Justice in Luxembourg.

There are other routes to environmental improvement. For example, in addition to strictly national programs, the EC provides funding for various types of studies, including research into developing cleaner industrial processes, recycling, and the like. Another is through formal, four-year EC environmental action programs.

Earlier this month, Carlo Ripa di Meana, the recently appointed EC Environment Commissioner, spoke of plans for setting up a European Environment Agency. This would be an independent body with a networking and coordinating role. Among its objectives would be linking the work of existing EC institutions with that of the European Space Agency, and examining the interplay between environmental considerations and broader economic factors.

Greenpeace/Van Der Veer photo

Incinerator ship **Vesta** *burning waste in North Sea*

In addition, there is what's known as the Single European Act adopted in July 1987. It is the first amendment of the 1957 Treaty of Rome, which enshrines the basic principles of EC law. The Single Act, as it is more generally known, gives environment politics a European dimension, as one observer puts it.

"For the first time in the treaties of the EC there is specific reference to environmental objectives," Bennett points out. "These are to preserve, protect, and improve the quality of the environment; to contribute toward protecting human health; and to ensure prudent and rational utilization of natural resources. The act makes provision for greater use of a system of majority voting within the EC's Council of Ministers to speed decision-making on environmental issues. This should assist us toward establishing a comprehensive framework for European environmental policy."

The Danish government set the proverbial cat among the pigeons in Brussels when it made a ruling that beer and soft drinks sold throughout the country must be supplied in returnable—namely, glass—bottles. The move, the Danes maintain, is to cut down on the amount of plastic waste and metal cans to be disposed of. But there were those in neighboring EC countries, and in the EC Commission, who saw it as a restriction on the free movement of goods, and a means of protecting Danish brewers' share of the home market. They also pointed to the fact that Danish brewers sell products on the export market in the type of one-way containers they are banning.

The upshot was that Denmark was charged with breach of the rules of the Rome Treaty, and brought before the European Court of Justice. It was the first such case to be tried since implementation of the Single Act. But to the surprise and dismay of many, the court came down broadly in favor of the Danes. The reasoning was that countries may take unilateral action on the basis of protecting their environment. West Germany has since taken a step in the same direction by imposing a mandatory deposit fee on plastic containers for all kinds of drinks. The deposit is high in relation to the selling price of the products.

One body concerned by the development is the Association of Plastics Manufacturers in Europe. Comments Peter G. Claus, APME's director in Brussels, "The West German decree will cause serious barriers to trade because of the high cost for exporters to the West German market in taking back empty containers. It will especially affect trade in mineral water that according to an EC directive on product purity must be bottled at source. The water cannot be transported in bulk for bottling in West Germany."

The government of the Netherlands, too, is causing a stir among EC officialdom by providing fiscal incentives to buyers of small and medium-size cars fitted with catalytic converters that clean the exhaust gas to U.S. standards. The U.S. standards are more stringent than those the EC adopted in November, and which go into force early next year. Here again the European Court of Justice is being asked to make a ruling on the issue, but that could take the best part of two years. Meanwhile, there's talk in Denmark and West Germany about moving to encourage purchase of cleaner cars. Greece plans tax incentives for cars that run on unleaded gasoline, and the U.K. has just introduced preferential pricing on unleaded fuel along the lines of policies in most other EC countries.

Opposition to the Dutch move comes mainly from car makers in France on the argument that "the whole [auto emissions] harmonization system in the EC risks tearing apart." But as Raymond Van Ermen, secretary general of the European Environmental Bureau in Brussels, sees it, "We cannot accept a system in which EC car makers produce cars that can meet the U.S. standards, but reserve them for export outside the EC.

"There are three levels of auto emission standards. The most lenient is that of the EC. The toughest is the U.S. Intermediate between the two is the standard of the European Free Trade Assocation (EFTA) countries. We in the EC are being treated as second-class citizens. In Austria, Switzerland, and elsewhere, you find cars made by well-known EC companies that respect U.S. and EFTA standards. So why not here?"

He adds that the European Environmental Bureau (EEB), which was set up in 1974 and to which 120 environment-related nongovernmental organizations within the EC belong, awarded its annual booby prize last year to Jacques Calvet, managing director of the French Peugeot, Talbot, and Citroën line of cars. "Mr. Calvet," the citation reads, "is head of a business that does not understand that the dynamism for protecting the environment is a part of management and the public image of a business."

C&EN staff photo

Bennett: not-in-my-backyard reaction

"The EC Commission," Van Ermen maintains, "takes the approach that environmental standards should be considered as a ceiling, a maximum, and the states should not be allowed to seek stronger measures. The other view, which EEB fosters, is that the standards serve as a floor, or minimum, with states able to use initiatives to achieve stricter environment policies."

The EC's first environmental directive relating to water was issued toward the close of 1973. It centered on "hard" detergents that, because of their persistence, were causing widespread problems to sewage-treatment plants. And, in addition to impairing oxygenation and photosynthesis, they produced unsightly foaming. Interestingly, it wasn't until almost 10 years later that a directive presenting quality standards of drinking water became effective. And it was in December 1985 that all discharges into groundwater, the source of about 70% of drinking water throughout the EC, had to be controlled.

Breach of drinking water directives, nevertheless, seemingly is common. The EC Commission recently has leveled criticism, and in some cases taken legal action, against Belgium, Denmark, France, West Germany, Italy, Ireland, the Netherlands, Spain, and the U.K. Likewise, the commission isn't pleased with the condition of many of the beaches that have been officially designated as swimming areas. Untreated sewage and other filth wash around the shores of some of the most popular vacation spots.

During the closing weeks of last year, scientists from seven EC countries aboard the *Discovery*, a 2100-ton research vessel owned and operated by the U.K.'s National Environment Research Council, sampled water, sediments, and biota in the Mediterranean Sea off the Rhône delta in southern France. The study was the first of a series planned under the EROS (for European River Ocean System) 2000 project. This is a long-term, multidisciplinary research program, supported by the EC and drawing on help from 25 institutions in 11 member countries, to chart river and atmospheric pollution of the EC coastline. Its aim is to enable better management of European seas and their biological resources.

It will take several months to complete analysis and interpretation of the 900 million or so data readings taken during the four-week cruise. But there are early indications of elevated concentrations of such nutrients as nitrates and phosphates

C&EN staff photo

Claus: serious barriers to trade

near the mouth of the Rhône and extending out to sea. Also, the role of certain microorganisms in the adsorption and breakdown of pollutants has been identified.

Subtle changes in the marine environment seemingly can give rise to unusual and sometimes serious consequences. This occured last summer when a planktonic algal bloom consisting of large quantities of *Chrysochromulina polylepis*, a single-cell flagellate, developed spontaneously in the sea between Denmark and Sweden. The carpet of algae was carried by currents westward along Norway's southern coastline. Because the alga produces a toxin that kills a variety of sea life, it resulted in damage and economic harm to the fish-farming operations in the region.

The toxin is a glycolipid similar to that found in *Prymnesium parvum*, to which *Chrysochromulina polylepis* is related. It functions by destroying cell membranes, and bringing about paralysis of infected organisms.

The bloom persisted for about four weeks in May and June before dissipating south of Bergen on Norway's west coast. At its height, cell counts of 80 million or more per liter of seawater were recorded. Mortality and damage to marine biota were registered from the surface down to a maximum depth of some 100 feet.

Analysis of seawater nutrients registered a rise above the more usual level of nitrate and a fall in silicate. "The contention is that this contributed to the situation," remarks John A. Berge of the Norwegian Institute for Water Research (NIVA) in Oslo, who with his colleagues there and scientists from a number of other facilities in Norway and Sweden, closely monitored and evaluated the occurrence.

"The explanation for the bloom centers on the nutrients," Berge says. "Where these came from is a matter of speculation.

"There has been a lot of documentation on previous algal blooms, but not on one of this particular [toxic] organism. If it is the case that this bloom marks the commencement of a period with more frequent blooms of toxic algae such as Chrysochromulina, the result in the long term may be the depletion of both algal and animal coastal communities."

It's considered unlikely that the toxic algal bloom was directly responsible for last year's widespread death of seals along the coasts of countries bordering the North Sea. Mortality among the seal population has been attributed to a virus akin to that which causes distemper in dogs. It might well be, however, that ingestion of the algae weakened the seals' resistance to the viral infection.

C&EN staff photos

Van Ermen (left): environmental rules should be considered as a ceiling. Johannessen: nitrogen level is up

Although the biota of Norway's fjords escaped the worst of the Chrysochromulina threat, they remain prone to the ravages of industrial pollution. Jens Skei, a marine geochemist at NIVA, is at the forefront of a series of research projects evaluating the environmental damage by effluents from a variety of processes.

The fjords, so characteristic of Norway's coastline, are long, narrow, steep-sided sea inlets cut by glaciers thousands of years ago. Many industrial operations have been sited at the head of the fjords to take advantage of relatively inexpensive hydroelectric power generated by water coming down from the mountains. "They can create pollution problems," Skei points out, "because effluents enter the water far from the open sea where there is very little dilution, unlike the river estuaries in other countries."

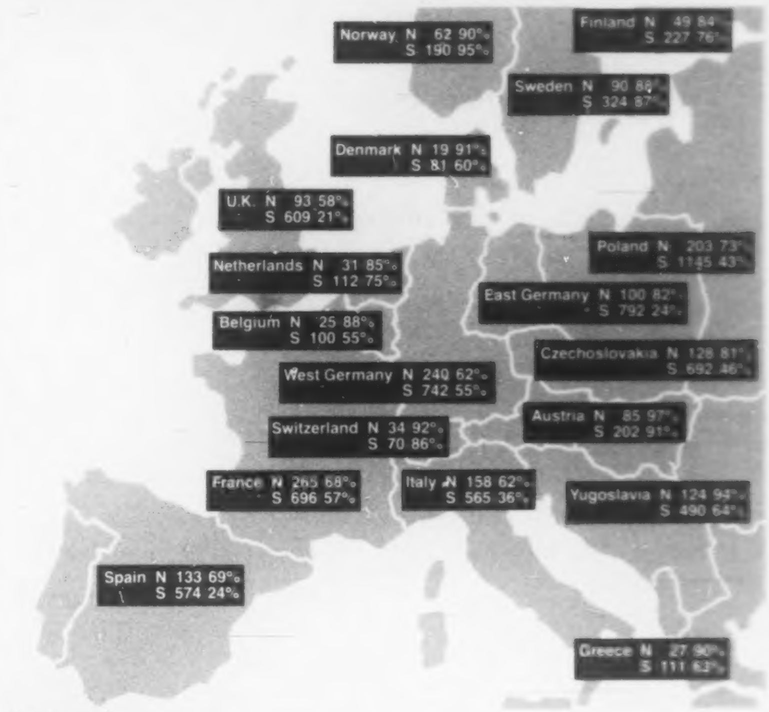
An example is the 120,000 metric-ton-a-year electrolytic zinc operation of Norzink at Odda at the head of Sørfjord to the east of Bergen. Dating from 1929, the company is jointly owned by Sweden's Boliden and BP Minerals. (British Petroleum currently is negotiating sale of BP Minerals to RTZ, which presumably will acquire the half-share interest in Norzink if the sale goes through).

"We found the bay stuffed with very high levels of such heavy metals as zinc, lead, copper, mercury, cadmium, and the like," Skei says. "Much of it had been dumped as solid waste creating enormous problems to the water quality and biota."

Partially as a result of the NIVA findings, Norzink has stopped putting the waste in the fjord. Instead, the company is depositing it in tunnels bored into the neighboring mountain at considerable expense.

Burying of waste also has resulted from studies Skei and his associates made of a titanium dioxide facility

Outside sources provide significant amounts of local nitrogen, sulfur depositions



How to read:

Belgium N 25 88%
S 100 55%

Average annual deposition of nitrogen and sulfur (thousands of metric tons) and percentage of deposition received from other countries.

Source: United Nations Economic Commission for Europe, European Monitoring & Evaluation Program

at Frederikstad on the seacoast, due south of Oslo. Belonging to Kronos Titan, owned by NL Industries, the facility has an annual capacity of 25,000 metric tons and uses the sulfate process.

Until recently, the red-colored acidic waste was discharged into the adjacent Glomma River at a depth of about 20 feet. The heavy metals content of the effluent and its high degree of acidity had an impact on the region's fish life and marine biota. So much so that Kronos Titan decided last May to pump the effluent into barges for shipment to a disused calcite mine in the Oslo fjord into which the waste is dumped.

Operations of Norsk Hydro, Norway's largest producer of chemicals, also came under Skei's scrutiny. One involved the discharge from a mercury cell chlor-alkali plant. Another centered on effluent from a unit that extracts magnesium from seawater. Both have been in service for the past 40 years or so at Porsgrunn on the Frierfjord, southwest of Oslo. The government imposed a fishing ban in the fjord because of the high level of toxic chemicals there.

"Some 40 metric tons or so of mercury had accumulated in the ground near the chlor-alkali plant. It was contaminating the groundwater, and there was some seepage into the fjord," he recalls. "In the bed of the fjord itself adjacent to the plant, there was a buildup of about 25 metric tons of mercury. Coming from the magnesium unit was an incredible cocktail of toxic chlorinated hydrocarbons, consisting of penta- and hexachlorobenzene, octachlorostyrene, decachlorobiphenyl, and the like, together with dioxins."

The chlor-alkali plant is now shut down. And an effluent treatment system is being installed at the magnesium plant that will reduce the outflow of chlorinated hydrocarbons 90% from the current annual level of about 250 kg. Yearly discharge of dioxins will be cut from 25 g to around 5 g.

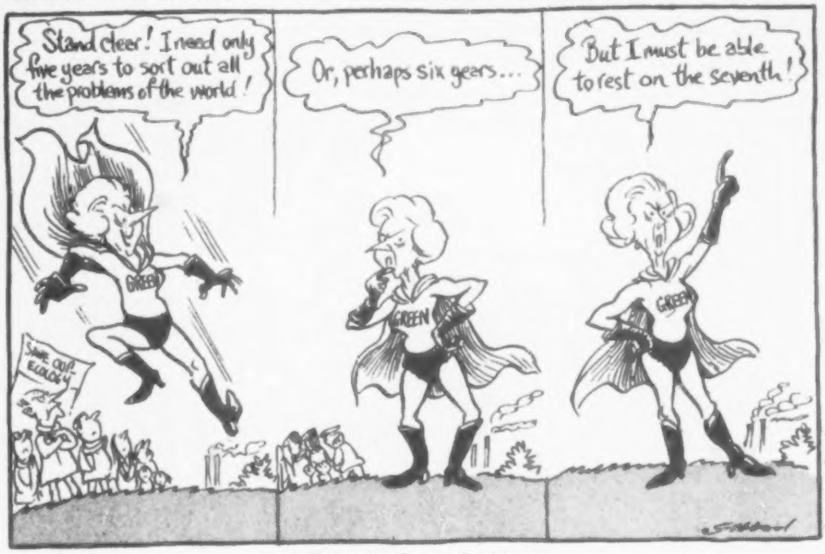
"Such studies usually are carried out at the behest of the Norwegian State Pollution Control Authority or the corresponding local bodies," explains Merete Johannessen, NIVA's director of research. NIVA staff members are free to publish their findings and discuss them at scientific meetings, she adds. Moreover, the results can be the basis of Norwegian and, at times, international action on environmental issues. NIVA also serves as the coordinating center for the United Nations Economic Commission for Europe's (UNECE) international cooperation program on assessment and monitoring of acidification of rivers and lakes.

Established by the state 30 years ago, NIVA since has severed its ties with the government and now functions as an independent, autonomous foundation. Still, up to 90% of its annual funding stems from government-related work. "We are directly involved with the use and protection both of Norway's fresh water and of marine water close to the coast," Johannessen notes.

She points to a recently completed survey of water quality in 1000 lakes throughout the country. "We found that the degree of acidity is about the same as it was in a similar survey made 10 years ago, in some cases showing pH values below 5. Sulfate ion concentration has come down, mainly due to lower levels of sulfur deposition. But we have identified an upward shift in the concentration of nitrate ions in the water. Seemingly greater quantities of nitrogen-containing compounds are being leached out of the catchment areas. The shift of anions from sulfate to nitrate maintains the pH of the lake water at the same low levels as before."

NIVA staff members maintain close liaison with their counterparts at the Norwegian Institute for Air Research, or NILU. There, Harald Dovland heads the Chemical Coordinating Center for a multinational air quality monitoring program within the Convention on Long-

Gibbard's view


Stand clear! I need only five years to sort out all the problems of the world!
Or, perhaps six years...
But I must be able to rest on the seventh!
GREEN
GREEN
GREEN
SAVE OUR ECOLOGY
Gibbard

Manchester Guardian

Enter the Green Goddess

One British cartoonist's view of Margaret Thatcher's pronouncements on environmental issues

Range Transboundary Air Pollution, drawn up under the aegis of the Geneva-based UNECE.

Signed 10 years ago by 34 countries—and the European Community as a bloc—that extend from Canada and the U.S. to the Soviet Union, the convention entered into effect in 1983 when a sufficient number of signatories had ratified it. It aims to "limit and, as far as possible, gradually reduce and prevent air pollution, including long-range transboundary air pollution."

A protocol to the convention adopted by 21 of the countries four years ago calls for a reduction by 1993 of sulfur dioxide in the air 30% below the 1980 emission level. And at last November's annual session held in Sofia, Bulgaria, another protocol was signed that has as its goal a reduction of nitrogen oxides to their 1987 levels by 1994. In addition, 12 countries signed a formal declaration committing them to a 30% reduction of NO_x emissions by 1998.

Within UNECE's European Monitoring & Evaluation Program, measurements have been taken for a number of years of airborne sulfur dioxide and sulfates, together with pH values and concentrations of major ions (ammonium, calcium, magnesium, sodium, chloride, and nitrate) of rainwater. The data are recorded at 95 monitoring stations throughout 24 European countries. More recently, analyses at some of these stations have embraced nitrogen dioxide and other nitrogen compounds in the air, as well as ozone.

Models of the weather conditions throughout Europe, which are continually being refined, have been drawn up at UNECE's two Meteorlogical Synthesizing Centers. The one responsible for Eastern Europe is at the Institute for Applied Geophysics in Moscow. That for Western Europe is located at Oslo's Meteorological Institute.

NILU's Dovland makes regular checks to ensure that the performance of participating laboratories is within specified standards. He also receives and collates the analytical data, and examines how they compare with what would have been anticipated from the meteorological models. Meanwhile, Anton Eliassen, research head at the Norwegian Meteorological Institute, looks at what the models indicate should have been deposited against actual deposition readings.

"The job is becoming very resource-demanding," Eliassen admits. "It takes more than an hour to integrate the information on the powerful Cray X/MP dual-processing supercomputer at Trondheim University that we are linked with. Indications are encouraging as far as airborne sulfur is concerned. Our calculations show that a reduction already is occurring," he says.

Jan Nilsson at the research and development department of Sweden's National Environmental Protection Board in Stockholm agrees that "Sulfur emissions and annual depositions are decreasing to some extent. We now have the 30% sulfur dioxide reduction agreement. A few countries aim for a greater decrease. Here in Sweden, the goal is a 65% cutback from the 1980 average."

On the other hand, Nilsson sees the acid rain problem in Western Europe, which is blamed partly on airborne sulfur oxides, to be "as big as ever it was. To some extent the reason for the recovery of the forests, or rather the halt in their decline, is that the climate has been so favorable for tree growth in the past few years. But the next time there's a climatic stress factor, such as a hot, dry summer, we will have another breakout of forest damage."

Nilsson is actively promoting the critical load concept, as he calls it. Indeed, by his own admission, he is "the mother and father of it." Simply put, the critical load factor is the load of acid deposition per acre below which no adverse effect on the ecosystem would be expected, even in the long term. The factor varies from region to region and from one chemical species to another.

A year ago, Nilsson helped organize a meeting in Sweden, cosponsored by UNECE and the Nordic Council, to which 16 of the countries that are party to the Convention on Long-Range Transboundary Air Pollution sent specialists. The 72 participants proposed "best estimates" based on current knowledge for critical loads for sulfur in forest soils and groundwater, for nitrogen in terrestrial ecosystems, and for sulfur and nitrogen in surface water systems. They also discussed the biological consequences of an excess nitrogen load to terrestrial ecosystems.

At last November's transboundary convention gathering in Sofia, environment ministers agreed that the critical load concept should be the

Dean and Chapter of Lincoln photo

Effects of atmospheric pollutants on the stonework of this grotesque that decorates Lincoln Cathedral in England are very evident

main basis for negotiations on emission control strategies. Arising from this, work is under way to draw up a manual explaining how to map for critical loads. "We hope that all the countries in the convention will do such mapping," Nilsson comments. "In this way, science will become a very important part of the policy-making process using ecosystem effects as a base, not just economics."

Nilsson expresses concern about the level of airborne nitrogen compounds, which he doesn't see decreasing in the near term. Besides, he adds, one of the key aspects of the critical load concept as it relates to nitrogen is the long-term accumulated amount of nitrogen in a given ecosystem rather than the actual amount deposited over a specific year. "Nitrogen-related damage might not show up for many years," he says. "We see nitrogen accumulation—whether as nitrate, or ammonia, or whatever—as one of the key environmental issues."

Also under the UNECE banner, a Europe-wide experiment got under way last year to assess the effect of air quality on crops. "We are starting out with the Cherry Belle radish, a variety particularly susceptible to damage from ozone," says Mike H. Unsworth, professor of environmental physics at Nottingham University in the U.K. who is coordinating the study. In 12 field sites participating in the project, the plants are grown under identical conditions, and the makeup of the air is continually monitored.

Half the plants at each station are watered with a solution of ethylene diurea, a Du Pont experimental chemical that protects against oxidants. Plants so treated should withstand high ozone levels in the air better than those that are not.

"Radishes are hardly a crop vital to most communities," Unsworth comments. "But they could well serve as an ozone marker."

With input provided by Patricia Irving, assistant director of the National Acid Precipitation Program in Washington, who has been engaged in similar experiments, 10 countries—Czechoslovakia, Finland, France, Italy, the Netherlands, Poland, Spain, Sweden, the U.K., and the U.S.—are taking part in the project. But Unsworth believes others will join as it proceeds.

Such multinational efforts centering on technical aspects of environmental problems are a counterpart to those involving political conferences aimed at treaties and conventions. Together, such activities illustrate the complexity of the issues, as noted by Ibsen's mayor, and are one indication that, with pollution readily crossing national boundaries, national go-it-alone attitudes toward the environment are changing. ☐

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EPA Urges Nations To Limit Greenhouse Gases, Protect Climate

Report to Congress provides a variety of policy options for U.S., international community to delay or lessen expected global warming

If Earth's climate is to be stabilized, governments must act to limit the buildup of greenhouse gases, says a draft report prepared for Congress by the Environmental Protection Agency. Policies ranging from fees on fossil fuels to preserving tropical forests could delay or lessen the global warming expected from the changing composition of the atmosphere, the report concludes.

Furthermore, action by the U.S. or even the industrialized world working in concert will not be sufficient to protect climate. All nations, including developing countries, must limit greenhouse gas emissions.

About two years ago, the Senate Committee on Environment & Public Works assigned EPA the monumental task of assessing what policies could stabilize current levels of greenhouse gases like carbon dioxide, methane, and chlorofluorocarbons (CFCs). The resulting report, "Policy Options for Stabilizing Global Climate," presents a diverse series of strategies that could be adopted not only by EPA and other U.S. government agencies but also by the international community.

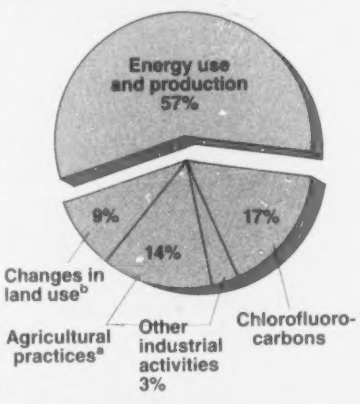
Although not yet in final form, the draft report is already receiving high marks from researchers and decisionmakers concerned about climate change. "The report is the best systematic effort ever into what options are available," says John C. Topping Jr., president of the Washington, D.C.-based Climate Institute. "It will be the premier document in the field for the next few years."

By flatly stating that the scientific community agrees that significant global warming caused by greenhouse gas emissions will occur throughout the next century, the report bypasses much of the current wrangling about whether greenhouse warming is already upon us (C&EN, March 13, page 25). It also avoids debates over how rapidly and how large a climate change will occur. Instead, the report uses state-of-the-art models to project what the world will be like under several scenarios.

A wide range of policy options are available to significantly slow the rate of greenhouse gas buildup and climate change, the report concludes. Among the steps the report suggests governments could take to cut emissions of greenhouse gases are the following:

- Impose emissions fees on fossil fuels such as oil, coal, and natural gas so that their prices reflect the risk of climate change. Such fees could encourage shifts to other energy sources and also raise funds to finance other programs.
- Require auto fuel efficiency to increase to 50 miles per gal (mpg) or more. Currently, new cars in the U.S. average 25 to 33 mpg.
- Cut residential and commercial energy use by improving building shells; lighting, heating, and cooling equipment; and appliances.
- Step up research on nonfossil fuel energy technologies, including solar, biomass, hydroelectric, geothermal, and nuclear energy.
- Phase out production of CFCs and halons. The 50% cutback of CFC output called for in the Montreal Protocol on Substances That Deplete the Ozone Layer is insufficient.
- Halt clearing of tropical forests and plant more trees. If current trends continue, most tropical forests could be lost during the next century.
- Encourage research into agricultural techniques, such as feed additives for cattle and water management in rice production that could reduce emissions of methane.

Worldwide, energy use dominates global warming



Note: Each activities' contribution to greenhouse warming for the 1980s is estimated based on its share of greenhouse-gas emissions. **a** Includes methane emissions from animals, rice cultivation, and use of nitrogenous fertilizer. **b** Includes deforestation and biomass burning.
Source: Environmental Protection Agency

Government policies also could make the greenhouse effect worse, the report points out. For instance, a policy to accelerate the development of synthetic oil and gas from coal could hinder conversion to nonfossil fuels.

International cooperation is essential to head off climate change, the report stresses—especially from developing countries. Although per capita emissions in developing countries are now very low compared with the U.S., Europe, Japan, and East bloc nations, the capacity for growth is much larger.

"If the developing countries don't

CO_2 may be increasing faster than EPA assumes

For years, carbon dioxide levels in the atmosphere have been growing about 1.5 ppm per year. However, that increase represents only about half of the carbon dioxide that is emitted to the atmosphere each year—the rest is absorbed by the oceans or the biosphere or both.

Now, however, some scientists are worried that the percentage of carbon dioxide that becomes airborne is increasing. If that turns out to be the case, the kinds of global climate changes that modelers are predicting for the future will occur more quickly than is now predicted.

"The carbon dioxide growth rate for 1987 and 1988 is the highest we've ever seen," says Pieter Tans, a physicist with the University of Colorado's Cooperative Institute for Research in Environmental Sciences (CIRES). Tans works with data collected by the National Oceanic & Atmospheric Administration's global monitoring for climate change program.

For the past two years, the network has recorded a yearly increase in atmospheric carbon dioxide of about 2.5 ppm. Tans points out that this accelerated rate of increase could be temporary: Two years is not long enough to establish a trend. If it is real, however, it can't be accounted for by increases in the burning of fossil fuels. "Something else is varying," Tans says.

What that something else is remains unclear. The oceans may be absorbing less carbon dioxide or there may be a change going on in terrestrial ecosystems. To sort out just what is shifting, additional information about the many sources and sinks of carbon dioxide is needed.

"It's important that there be precise measurements of carbon dioxide all over the world," says C. David Keeling of Scripps Institution of Oceanography, which is part of the University of California, San Diego. Keeling heads a group that has been continually measuring carbon dioxide in the atmosphere since the 1950s. His researchers not only measure the abundance of carbon dioxide but also make isotopic measurements that indicate whether the gas is coming from land or the oceans.

In the meantime, the apparent change in the carbon dioxide growth rate is making many people nervous. "Hopefully, this is an anomaly," says Climate Institute president John C. Topping Jr. "There could be devastating consequences for Earth if, say, 70% of CO_2 emissions are becoming airborne instead of 50%."

buy in early to the idea that emissions should be reduced, what the industrialized world does will hardly matter," Topping says. "We have to get involved in a serious effort to make technology available so that there doesn't have to be a tradeoff between economic development and protecting the climate."

Topping believes developing countries will be more willing to participate in measures to control emissions of greenhouse gases if they perceive such action as in their interest. It is in Third World countries, he says, where the human toll of drought or coastal flooding brought about by climate change is most likely to be exacted.

"As a practical matter, people aren't going to starve to death here," Topping says. "But it is possible in marginal agricultural-based societies." He suggests the U.S. invest—perhaps through the United Nations Environment Program—in funding studies by scholars in developing nations of the likely local impacts of climate change.

Reducing greenhouse gas emissions can serve other desirable goals in industralized nations, too, the EPA report points out. For example, phasing out CFCs will also serve to protect Earth's deteriorating ozone layer (C&EN, March 13, page 4). And acid rain and dependence on imported oil could be lessened by policies that encourage a switch away from fossil fuels.

The draft report is now under review by EPA's science advisory board. Once revised and finalized, probably sometime in April, it will be sent to Congress—where global climate change is already a hot item on the legislative agenda.

Pamela Zurer

U.S. vexed by spread of chemical weapons

The thorny issue of chemical weapons proliferation is getting thornier. Recently it became public that a Swiss company had supplied Egypt with equipment for a plant that could be used to make chemical weapons. Iran has contacted the same Swiss engineering firm, seeking equipment to build a plant capable of producing phosphorus pentasulfide, a worrisome chemical.

The U.S. is in a bind. It has assumed a major role in stemming the global spread of chemical arms, and was quite vocal when Libya received Western aid to build an alleged chemical weapons plant. Now Egypt appears to be getting the same kind of Western help. But, unlike Libya, Egypt is the U.S.'s major Arab ally in the Mideast, the recipient of more than $2 billion in U.S. military and economic aid this year.

The U.S. has been noticeably less vociferous about the Egyptian acquisition. Although the Swiss Foreign Ministry acknowledges that the plant was intended to make chemical weapons, the U.S. has not called for the dismantling of the Egyptian plant as it did for the Libyan one.

In fact, the U.S. has deflected the Egyptian affair slightly by focusing on the Swiss-Iran link and by calling for an international conference on proliferation. The call for a conference came in Vienna in early March.

Then at a meeting on conventional forces in Europe, Secretary of State James A. Baker III announced that there will be a meeting of governments, and chemical industry representatives to explore ways of halting the international trade in chemical weapons precursors and technology. Organized by Australia, the meeting is expected to be held in late fall in Sydney, says Kyle B. Olson, chemical warfare expert for the Chemical Manufacturers Association.

CMA is helping the State Department compile "a list of appropriate industry people throughout the worldwide chemical industry," Olson says. The trade group is also developing a series of measures to help chemical firms deal with the

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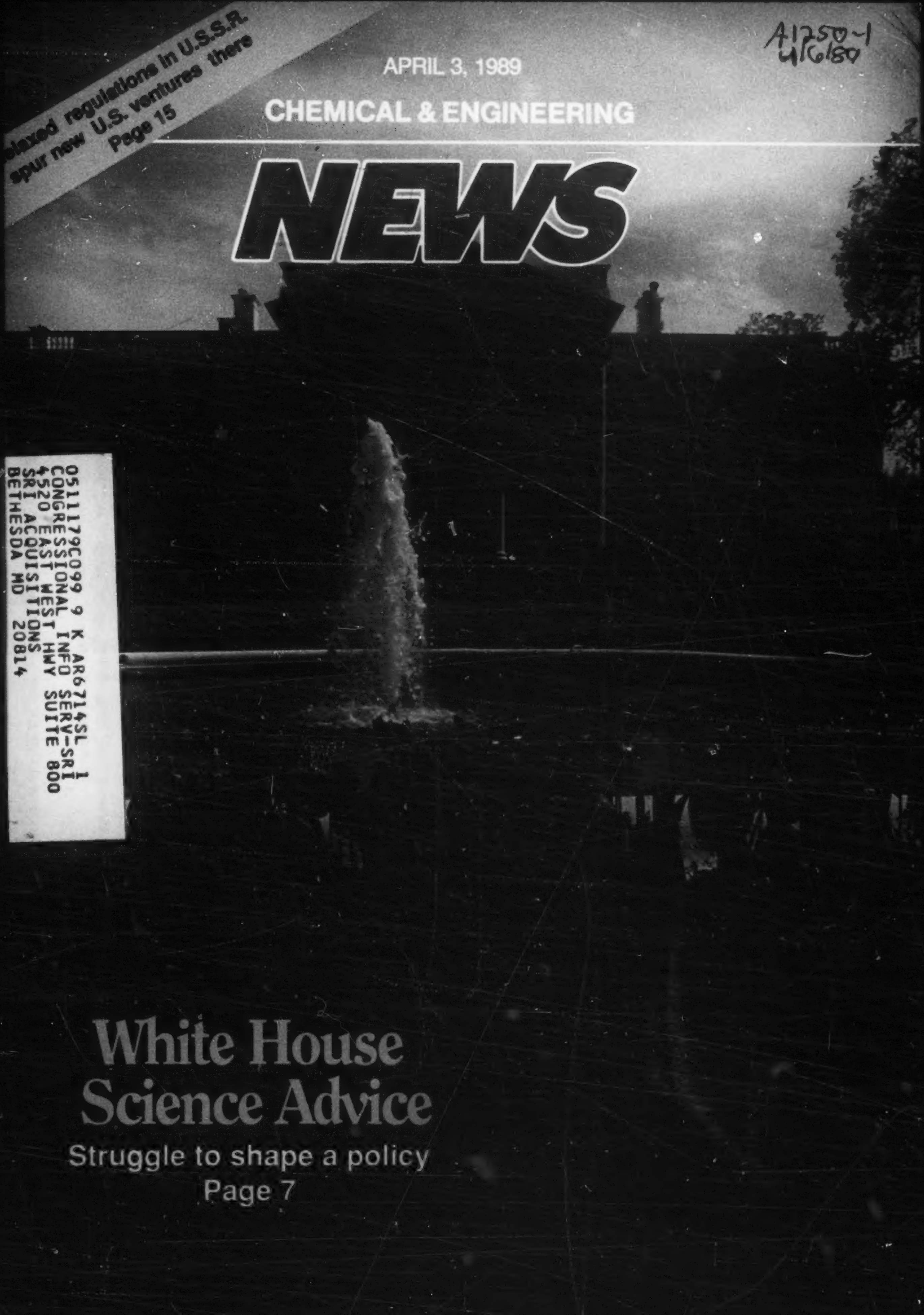
APRIL 3, 1989

CHEMICAL & ENGINEERING

NEWS

elaxed regulations in U.S.S.R.
spur new U.S. ventures there
Page 15



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White House Science Advice

Struggle to shape a policy
Page 7

CHEMICAL & ENGINEERING
NEWS

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APRIL 3, 1989

News of the Week

- **Utah electrochemists' disclosure that they have achieved nuclear fusion at ambient temperatures in an electrolytic cell has triggered excitement and skepticism among scientists.** Page 4
- **USDA is stepping up its biological control efforts, including initiation of joint research with the Soviet Union and China.** Page 5
- **Warner-Lambert suit charges Rohm & Haas with supplying a pesticide-contaminated resin for use in a cholesterol-lowering drug.** Page 6
- **American Chemical Society officials discuss science education, risk assessment, other issues with White House aides.** Page 6

Business

U.S. joint ventures in the U.S.S.R. are on the upswing as a result of Soviet softening of bureaucratic controls, other regulations. **Page 15**

Former EPA chief Lee Thomas is heading up Law Environmental, an environmental engineering and earth science consulting firm. **Page 19**

Government

International controls on transboundary movement and disposal of hazardous wastes agreed to at Basel convention. **Page 21**

Increased regulation on the release of toxic chemicals by industry called for by several Congressmen. **Page 23**

Defense report lists 22 technologies deemed vital to maintaining and improving nation's defense. **Page 24**

Concerns of possible conflicts of interest among Superfund contractors are raised by General Accounting Office study. **Page 25**

Science/Technology

Nitrogen for blanketing provides growth area for gas separation; industry applications include safety blankets and controlled and transport atmospheres for preserving perishable foods. **Page 27**

News Focus

Debate over science advice in the White House continues as various groups air their thinking about its role, await the President's selection of a science adviser. **Page 7**

Cover: Photo of White House by Paul Conklin/
Uniphoto Picture Agency

Letters 2
Editor's Page 3

Concentrates

Business 13
Government 20
Science/Technology 26

The Departments

ACS News 30
Meetings 31
People 47
Newscripts 48

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LETTERS

Energy consumption

SIR: In reference to Joseph A. Counsil's letter (C&EN, Jan. 30, page 2), there are other, major problems regarding the relationship between energy consumption and economic activity in an increasingly service-oriented economy.

However flawed older energy consumption statistics may be, we tend to ignore the importance of fuel wood and animal fodder in the 19th and early 20th centuries. John Fisher has presented these data usefully in his "Energy Crises in Perspective" [Wiley, New York (1974)].

Over the years we have come to measure energy consumption with increasing accuracy and to place commensurate confidence in government statistics on some energy subjects. However, as those who study economic activity have observed, no such confidence is warranted when discussing the gross national product. Thus measures of ratios between energy use and gross national product should be regarded as suspect; this was first emphasized by Peter Gutman ("The Subterranean Economy," *Financial Analysts Journal*, November/December 1977). Gutman later believed that real economic activity exceeded official gross national product 14%. (The overwhelming portion of the underground economy consists of otherwise licit behavior and is not much affected by the level of criminal enterprises.) Edgar Feige, who set out to disprove Gutman ("How Big Is the Irregular Economy?" *Challenge*, November/December 1979, page 5), now thinks that Gutman systematically underestimates the off-the-books economy by a factor of two thirds (*Business Week*, April 5, 1982, page 64).

But Gutman and Feige do agree that in the U.S., as elsewhere, the level of underground economic activity has increased sharply in recent decades—both absolutely and as a percentage of officially reported gross national product. The effect is to understate the energy efficiency of the U.S. and other economies and to do so more each year.

There are several reasons why this is so. The economy is shifting to those sectors where income is more easily disguised. High marginal tax rates foster tax evasion. And both the complexity of taxation and the frequency of tax reform—which adds a lottery component to U.S. taxation—make it costly or even impossible to minimize the expenses of legal compliance.

The U.S. chemical industry, among others, is disadvantaged by the lack of predictability of future tax rates. Since taxation is a major determinant of income, repeated efforts to reform tax policy increases the investment uncertainty for U.S. industries relative to that of their foreign competitors.

E. R. Habicht Jr.
Port Jefferson, N.Y.

Changing public perception

SIR: "Chemical dependency" is rapidly becoming the accepted newspaper euphemism for drug, alcohol, and tobacco addiction. This unhappy usage adds to the existing negative connotations for chemistry and chemicals from such word combinations as "chemical wastes," "hazardous chemicals," and, of course, "chemical warfare."

It is evident that chemistry does not have a good public image these days. The common word linkages noted above are not doing much to improve that image. At least in the instance of the phrase chemical dependency, chemists ought to be active in pointing out that such usage is not only inaccurate but possibly harmful.

We are, of course, all addicted to chemicals, the vast majority of which are essential to life. Individuals who are addicted to drugs, alcohol, and so on are not benefited by attempts to soften the impact of their problems by employing words to describe them that are believed more socially acceptable. In fact, such usage may be injurious by delaying acceptance that a serious problem exists.

In the longer run, chemists should make a strong public case for the many positive contributions that chemistry and chemicals have made and upon which our modern society depends for agriculture, housing, health, clothing, and transportation. Changing a public perception is difficult but by no means impossible. (Note that in only a few years the image of Japanese-made articles went from "junk" to "high quality.") Cleaning up waste dumps is only one problem that faces the chemical industry today. Cleaning up its image may be equally daunting, but all chemists can and should participate by seeking to educate their fellow citizens. Start with the elimination of the phrase chemical dependency.

D. J. Berets
Stamford, Conn.

Correction

- March 20, page 44: Photo shows Prolabo Microdigest A300 automatic digester, not the Prolabo Maxidigest as was intended.

Soviet Loosening of Regulations Paves Way to U.S. Ventures There

Chemically related ventures aim to increase exports, hard currency, consumer goods, decrease imports, and enhance technological abilities

Ann M. Thayer,
C&EN Northeast News Bureau

One part of the Soviet Union's current perestroika, or restructuring, policy is aimed at overcoming deficiencies in the technological and industrial base of the Soviet economy. New government policies are de-emphasizing state central planning and are loosening the bureaucratic controls that have nearly paralyzed Soviet industry. The upshot is that as of April 1, it is easier for foreign companies to do business in the Soviet Union.

Modernization and "chemicalization" of Soviet industry are important aspects of the economic reforms (C&EN, Jan. 18, 1988, page 28). Before perestroika, the Soviets tried unsuccessfully to build up their chemical industry through the licensing of technologies and purchases of equipment and turnkey plants from outside the U.S.S.R. But, rather than decreasing their need for imported goods, they created a secondary dependence on foreign equipment imports. Delays as long as 10 to 15 years in construction and operations have left the Soviets with an outdated and ineffective chemical industry.

Although the Soviets manage to be leading producers of fertilizers, rubber, and ammonia, they rely heavily on imported chemicals. The chemical production they have depends heavily on foreign technologies. For example, as much as 90% or more of polyethylene and polypropylene production, and 50% or more of polyvinyl chloride and polystyrene production is on imported equipment. As worldwide prices of oil have dropped, their supply of hard currency from petroleum exports has all but dried up.

Eades: a tremendous opportunity

With the desire to increase exports, hard currency revenues, and domestic supplies of consumer goods, while decreasing dependence on imports and enhancing their technological and managerial abilities, the Soviets are expanding the role that foreign investors can play. The Soviets are looking for progress through developing joint ventures with foreign companies in the Soviet Union. This month, the most recent changes in the joint venture laws become effective.

The joint ventures are aimed at Soviet efforts to emphasize the production of plastics, petrochemicals, fibers, plant protection agents, and pharmaceuticals. PlanEcon Inc., a Washington, D.C.-based research firm that follows the Soviet economy, indicates that the pace of joint ventures has picked up dramatically since the Soviet Joint Venture Decree of January 1987. There were 23 joint ventures with foreign partners at the end of 1987. By the end of January 1989, only two years after the original decree, 205 ventures had been established. At this rate, says Jan Vanous, research director at PlanEcon, the share of joint ventures in the Soviet economy will reach 60% by 1995.

Nearly 80% of the ventures are with western countries. Whereas Finland, Austria, and West Germany account for 42% of the total number, the West Germans and Italians have invested the most money. About 18%, or $80 million, of the total investment in joint ventures is in about a dozen petrochemical or chemical ventures registered by the end of 1988. The average investment in the chemical sector is about $7.3 million.

Many of the earliest ventures are working toward modernizing existing facilities. A joint venture called STERCH was formed in 1988 between Honeywell and the Ministry of Mineral Fertilizer Production to provide process control systems. Honeywell's Austrian subsidiary owns 49% of the venture and contributes the systems and management expertise. STERCH recently completed a $2.2 million contract awarded last year as part of a pilot program to launch the venture. This year STERCH has been awarded three contracts, totaling $8 million, for the upgrading of ammonia fertilizer manufacturing units. Similarly, Combustion Engineering Inc. joined with the Ministry of Oil Refining & Petrochemical Industry in late 1987 to provide control systems and instrumentation for the chemical processing industries.

Combustion Engineering also heads a consortium of McDermott International, Mitsui Co., and Mitsubishi Corp. to construct two petrochemical complexes with the oil ministry in Surgut and Tobolsk in Western Siberia. Feasibility studies are under way and the cost of the projects is estimated at $20 billion. Reportedly, Combustion Engineering is involved with a Japanese consortium that consists of Mitsubishi, Mitsui, and Chiyoda Corp. working with the Ministry of the Chemical Industry to build a petrochemicals facility near Nizhnevartovsk. This facility is estimated to cost $5 billion to $6 billion. Western Siberia has been targeted as the location of several major projects because the region has enormous reserves of oil and natural gas.

Occidental Petroleum Corp., as part of an international consortium including Enimont of Italy, and Marubeni Corp. of Japan, signed a letter of intent with the oil ministry in March 1988. The consortium will build a $6 billion petrochemicals complex in Tengiz near the Caspian Sea to produce sulfur, ethylene, propylene, polyethylene, polypropylene, and other associated products. The consortium has a 49% ownership in the venture.

Because Tengiz is a grass-roots facility, the Soviet partner is not a private company but a government ministry, which, under the reorganized Soviet trade laws, can deal directly with foreign partners. "It's been a long process," says J. Roger Hirl, president and chief operating officer of Occidental Chemical Corp., who has participated in the negotiations with the Soviets. "After the Ministry of Foreign Trade was disbanded, the other ministries did not have the expertise in world business. They have been in a learning process, which exacerbates the difficulties in dealing with them."

Since the joint ventures are being used as a means to learn about western business practices, economics, and technology, the Soviets are often accused of being disorganized and ill-prepared for negotiating. "I don't know whether it's the system or the desire to build 30 major projects in a short time frame," says Hirl. "Their appetite far exceeds their abilities. They want to get from point A to point B in about 10% of the time it really takes to get there." And it's still too early to tell if the trade-off between working with an immense, centralized bureaucracy or with disjunct and, currently, inexperienced units is for the better.

Hirl: dealing has been long process

But, despite the difficulties, there are overriding incentives to doing business in the Soviet Union. Among these are a foothold in the potentially enormous Soviet marketplace, and access to abundant and relatively low-cost raw materials. "Supplies of raw materials are not a concern," says Hirl, "but the ability to get the finished product out of the Soviet Union and be competitive in world markets is." Tengiz is reportedly an inhospitable location with poor access by roads or rail, and little, if any, infrastructure to support industry. Concern is often expressed over the lack of support services because uninterrupted sources of energy, materials, and transportation are not to be taken for granted in the Soviet Union.

A feasibility study for Tengiz has been submitted to the Soviets for review and the outcome is expected any day. As part of the agreement, no less than 50% of the products are to be exported to help ensure the foreign partners of their profits in hard currency. Hirl believes that the increase in Soviet exports will not have a significant effect on world markets. "By the time the plants are on stream," he says, "it's our opinion that the market areas, being Western Europe, Latin America, and the Far East, will have developed to the point where the capacity will be absorbed in the marketplace."

Occidental Petroleum is also part of a project with the Ministry of the Chemical Industry to construct and operate two plants at the Kalush Petrochemical facility in the Soviet Ukraine. The $160 million to $200 million project is awaiting final approval by the Soviets. If the license is granted in the second quarter of this year as expected, it will take about two years to complete the project. The two plants will produce about 100 million lb each of PVC, with 25% percent of the output to be exported.

The experiences of Huntsman Chemical Corp. illustrate some different aspects of dealing with the Soviets under the joint venture laws. Huntsman, a producer of polystyrene, has formed a joint venture with AeroMar to produce plastic food service products. AeroMar itself is a new airline catering joint venture between Marriot Corp. and Aeroflot, the Soviet airline.

Huntsman was prompted to file an application for majority ownership after an announcement of the recent changes in the Soviet law. The change resulted from concern that the former limit of 49% ownership by the foreign partner was an impediment, especially in ventures with multiple partners. Ownership, as defined for a Soviet joint venture, has a catch. Although the foreign partner may own a 99% share and provide most of the capital, the managing board need not reflect the share ownership, and the Soviets are requiring that decisions on fundamental issues be unanimous.

This necessitates negotiating a very detailed agreement. Huntsman is dealing directly with the Soviet company, also only recently allowed, and finds them eager to learn about western business practices during the process. "I feel as comfortable with the people that I am

Soviets set up framework for joint ventures

The Soviet Joint Venture Decree of January 1987 outlines provisions for the operation of joint ventures with foreign partners. To address issues that arose in the past two years, and to make joint ventures more attractive, two supplemental decrees have been made, one in September 1987 and one in December 1988. Here, in brief, are descriptions of the major elements of the joint-venture laws.

Establishment. Three phases of development for the venture are defined: preliminary discussions leading to a letter of intent, negotiations encompassing a feasibility study and construction of the joint-venture agreement, and approval and registration of the venture with the Soviet authorities. For the venture to survive, its charter and activities must, in some sense, satisfy goals set by the Soviets for their economic system.

The decree presents only a basic framework and directs the partners to construct a comprehensive and detailed final agreement. The agreement must specify all structural and operational aspects of the joint venture, including such items as the nature of the business; its objectives, ownership, layout, management, accounting and operating policies; conditions for the sharing of profits, protection of property, resolution of disputes, termination of business, funding, and contributions by the partners.

Ownership. A limit of 49% ownership by the foreign partners, as determined by their contribution to the venture fund, has been changed in the December decree to allow for a majority ownership of anything less than 100%. But the Soviets have added the condition that all "fundamental issues" must be decided unanimously. The partners can specify in the contract those issues considered fundamental.

Capitalization. Contributions to the venture fund can consist of buildings, equipment, land and natural resource rights, cash and other assets, and technological and managerial expertise. The value of these contributions must be assessed with regard to "world market prices." This assessment was to be made in rubles, but the September decree provided an option to have the valuation based on foreign currencies.

Management and operations. A venture will be managed by a board consisting of members from all partners, but representation on the board need not relate to the percentage ownership. The organization, powers, and responsibilities of the board are determined by negotiation. Under the December decree, a foreign citizen can be director of the venture. The firm must employ primarily Soviet citizens and comply with Soviet labor laws; however, joint ventures have been extended the rights to hire and fire employees and to set pay and incentives.

Buying and selling. Joint ventures may buy and sell on the Soviet market either directly or through a government trade organization using either rubles or hard currency. The foreign trade system in the Soviet Union has recently been reorganized, with individual ministries being given more control. The December decree has extended these rights even further allowing Soviet enterprises to engage directly in foreign trade.

Profits and taxes. The foreign partner shares in the profits of the venture in proportion to the percentage ownership. Profits will be taxed at a level of 30% after a two-year tax holiday that begins when the venture declares a profit. Foreign partners can transfer profits out of the Soviet Union in hard currency but these will be taxed an additional 20%. An important stipulation of the decree requires that "all foreign currency expenditures of a joint venture, including the transfer of profits and other sums due foreign partners, . . . shall be covered by proceeds from sales of the joint venture's products on foreign markets." Thus the venture must be self-sufficient in terms of available hard currency. The ability of the foreign partner to obtain hard currency directly is also tied to export sales.

Other more general, yet significant, changes in the Soviet economy affecting joint ventures are mentioned in the December decree. A new exchange rate for the ruble is expected in January 1991. In the meantime, the ruble will be devalued 50% as of January 1990. The decree also directs Soviet authorities to complete a study by the first quarter of 1989 and make proposals for the convertibility of the ruble. Tax breaks and other privileges also may be granted to promote ventures in the far eastern economic area of the Soviet Union.

dealing with as I've felt with any western country or company," says Michael C. Eades, Huntsman vice president of corporate development and manager of the Soviet project. "We have no reason to doubt that they're not going to perform in all the categories that we've negotiated."

Still, as with any business, there will be risks. For businesses in the Soviet Union, assessing those risks may be more difficult because of uncertainties arising from transitions in the economic system. Some believe that risks in the Soviet Union are higher than elsewhere, others disagree or at least accept those risks. "We would not do business unless we could project some type of return," says Eades. "There is tremendous opportunity for any company that wants to do business over there, but they're going to have to be very well capitalized, very patient, and not expect immediate return." He also cautions that the level of return is not so identifiable as with western ventures.

"The long-term return is as advantageous as anything else that one could possibly consider doing anywhere in the world," he comments. "The market for consumer items is just tremendous, you cannot satisfy the need, you cannot saturate the market." However, trying to serve only the Soviet domestic market can present tremendous obstacles. One conflict is between the Soviets' desire to produce products for export, and the foreign partners' interest in selling to the large Soviet market. Foreign partners will not be interested in exporting to an already well-serviced world market.

A stipulation in the joint venture decree adds to this dilemma. It re-

Finland has most Soviet joint ventures . . .

	Number of ventures
Finland	28
Austria	26
West Germany	26
Italy	14
U.S.	13
Switzerland	10
U.K.	9
Hungary	8
France	8
Japan	8
Canada	6
Other	35
TOTAL[a]	191

. . . but West Germany invests more

	$ Millions
West Germany	$ 66
Italy	62
Yugoslavia	43
France	43
Finland	35
Austria	35
Switzerland	33
Japan	30
U.S.	23
Canada	17
Sweden	13
Other	41
TOTAL[b]	$441

[a] As of Dec. 31, 1988. [b] As of Dec. 29, 1988. **Source:** PlanEcon Inc.

quires that all hard currency expenditures of the venture, including payments of profits to the foreign partner, result from export sales. This would suggest that the Soviets' stated goal of taking care of domestic needs is secondary to their desire to ensure themselves of an export market to earn hard currency. This also means that the ventures must be self-supporting—independent of the government subsidies of hard currency frequently granted to Soviet businesses. Under these limitations, exports have apparently become the only direct source of hard currency from the venture for the foreign partners.

Of course, the venture can earn and spend rubles, particularly on its expenses within the U.S.S.R. But rubles are not an exchangeable currency and under the fixed Soviet exchange rate are greatly overvalued. To make trading in the Soviet market realistic, the ruble must be made convertible and prices within the Soviet Union must reflect world market prices.

If the ruble were made convertible, getting one's profits out no longer would be a problem. A change to convertibility could have drastic effects on both the economic balance of a foreign investment and on the Soviet society. "Economists in the Soviet Union are talking about eventual convertibility," explains Peter J. Pettibone, cochairman of the Legal Committee of the U.S.-U.S.S.R. Trade & Economic Council and partner of the New York City-based law firm of Lord Day & Lord, Barrett Smith. "The difficulty is putting it into operation and keeping a lid on the social problems that will undoubtedly result when there are radical price adjustments."

If the ruble is not made convertible in the near future, a means must be devised to get hard currency out of a venture if, as in the case of AeroMar, it does not have a large export market and a large proportion of its profits are in rubles. One option is an exchange auction that was proposed by the Soviets on an experimental basis this year, but may be postponed. Hard currencies and rubles, at a rate that may differ from the fixed Soviet rate, can be bought and sold at currency exchange auctions. "Even so," says Pettibone, "there is considerable doubt as to whether joint ventures are going to be allowed to participate or, if they are allowed, joint ventures may only be allowed to sell hard currency."

The foreign partner may wish to take its profits in raw materials or products, an approach that has great potential in the petrochemical industry. But during a recession, this can cause a glut on the world market as happened in barter deals in the early 1980s. Another possibility is to take advantage of the freedom granted joint ventures to buy and sell goods in the Soviet market for either rubles or foreign currencies. Sales of products from a venture could be made, either all or in part, for hard currencies completely within the Soviet Union. However, a venture may be forced to spend hard currency when a supplier asks for the same conditions.

Despite these major obstacles, such as the exchangeability of the ruble and hard currency issues, there is generally a good amount of optimism, tempered with caution, about setting up joint ventures in the Soviet Union. Optimism stems, to a large extent, from the willingness of the Soviets to educate themselves in the areas of western economics and business, and their desire to make technological advances. As the Soviets move farther along their learning curve, more companies are exercising the freedom to participate in joint ventures, negotiations are becoming easier, and the attitudes toward joint ventures are becoming more positive. An attitude expressed by both the U.S. and Soviet sides is that the atmosphere for trade will improve further if laws linking favorable trading status to human rights issues are either waved by the U.S. government or their conditions satisfied by the Soviets.

U.S. partners in joint ventures, such as Huntsman and Occidental Petroleum, report that they have not faced serious obstacles to doing business from the U.S. side. To export some technologies to the Soviet Union, a license may be needed from the U.S. Department of Commerce. Although Commerce is said to be speeding up the processing of licenses, it still may take a few months to obtain approval. Limitations are expected primarily in technologies that involve computerization, highly pure chemicals for electronics, and chemicals related to warfare or nuclear weapons. However, seemingly harmless products may also be restricted because of the embodied technology. Petrochemical and chemical ventures often do not involve strategic technologies.

The probability for success in petrochemical and chemical joint ventures is quoted as being very high. "It's difficult to do wrong," says Vanous of PlanEcon. He attributes this to the Soviets' very much needed boom in growth, the abundant supplies of natural resources, and the low labor requirements in the chemical industry. □

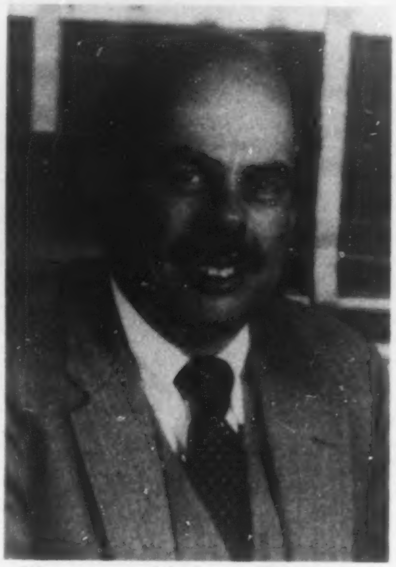
Tougher laws on toxic emissions urged

Citing preliminary data from the Environmental Protection Agency's toxic chemical emissions inventory, several Congressmen are calling for increased regulations on the release of allegedly toxic chemicals by industry. In response, chemical industry representatives say they are already well on their way to reducing pollution and that intimating health problems from current emissions is wrong.

In a short report based on data supplied by EPA, the House Subcommittee on Health & the Environment says that, according to industry estimates, 2.4 billion lb of toxic chemicals are released into the air annually. About one third of that, 887 million lb, comes from the chemical industry. Subcommittee chairman Henry A. Waxman (D.-Calif.), a longtime advocate of stricter federal regulation of air emissions for the chemical industry, says: "The magnitude of the problem far exceeds our worst fears. It is essential that we have a strong and effective air toxics program as part of the Clean Air Act amendments that will be moving through Congress this year." He, along with Rep. Mickey Leland (D.-Tex.), Rep. Gerry Sikorski (D.-Minn.), and Rep. James Florio (D.-N.J.), plans to introduce legislation that would bring further controls to chemical emissions soon.

Waxman makes the jump from the emissions inventory to the impact these emissions have on people's health. "Such high levels of toxic releases are sure to be accompanied by comparably high levels of human suffering," he says. Waxman cites studies that show higher-than-average cancer incidence near chemical facilities and subcommittee testimony from individuals who relate their personal health problems to their proximity to a chemical plant. Florio agrees and blames delays by EPA for putting people at risk.

"My fear is that people are facing very serious health risks," Florio says. "EPA intends to spend upwards of $400,000 during fiscal 1989 on so-called risk communication strategies designed to convince the public that these releases are of minimal concern. I wonder why these dollars weren't spent to establish much-needed standards for the carcinogens and neurotoxins [listed] in this report."



Waxman: problem exceeds our fears

The EPA data present emissions on a state-by-state basis and give the total emissions of each of the listed chemicals. Some examples are pulled out by the subcommittee to show how serious the problem is. One is the listing of 69,000 lb of phosgene emitted annually. According to EPA, that all seems to come from just one plant in Kansas, and it may have been an accidental release. The agency doesn't know yet. Other examples focus on the relatively large amounts of emissions in the Houston and the Great Lakes areas, where there happen to be large concentrations of chemical industry facilities. The report also pulls out the data on chemicals that the subcommittee says are listed as carcinogens by the U.S. Public Health Service's National Toxicology Program.

Data used by the subcommittee come from a provision in the 1986 Superfund Amendments & Reauthorization Act that is directed toward community right-to-know and emergency preparedness with respect to chemicals. One section of that provision, Section 313, requires that any facility that produces or imports certain volumes of any of more than 320 chemicals that have been designated by Congress as acutely toxic must provide EPA with an estimate of how much of each of these chemicals is emitted into the air at every facility. These inventories of chemical releases during 1987 were due to EPA on July 1 last year. At that time EPA expected nearly 300,000 reports from 30,000 facilities. That expectation has been lowered now that EPA has received only about 75,000 reports from fewer than 17,500 plants so far. EPA estimates these reports are only 55 to 70% of the total number required. Even the total emissions figure (2.4 billion lb) may be a small percentage of the total because it does not include thousands of small companies that emit these chemicals. There is another deadline this July 1 for the second annual inventory. The subcommittee report uses raw data from the first inventory for its conclusions.

Although Waxman singles out the chemical industry as the largest source of these chemicals, the industry does not see itself as part of a great national problem. Randal P. Schumacher, director of health, safety, and environmental programs for the Chemical Manufacturers Asso-

Chemical industry tops list for toxic chemical emissions

Millions of lb	SIC code	Total air emissions
Chemicals	28	886.6
Primary metals	33	215.1
Paper	26	207.9
Transportation equipment	37	192.0
Rubber and plastics	30	132.0
Fabricated metals	34	110.2
Electrical and electronics equipment	36	89.7
Petroleum and coal	29	75.5
Machinery	35	46.2
Furniture and fixtures	25	45.3
Instruments	38	41.6
Textiles	22	34.9
Stone, clay, and glass	32	25.7
Lumber and wood	24	25.0
Miscellaneous manufacturing	39	21.7
Food	20	15.7
Leather	31	7.5
Apparel	23	2.1

Source: Environmental Protection Agency

ciation, says that chemical companies have worked very hard, particularly since the Bhopal, India, disaster, to reduce their chemical emissions and recycle waste more efficiently. Concerning the numbers Waxman released, Schumacher says, "While the numbers are high, they are just estimates. We in the industry were given assumptions to use by EPA when calculating the levels of emissions, especially fugitive emissions, that probably give high numbers." Schumacher says that it must be remembered that the data are for 1987 and that a number of chemical industry programs have already reduced air emissions substantially.

Both CMA and EPA are concerned about the subcommittee's contentions that the listed emissions cause disease. Schumacher says it most strongly: "The allegations between the raw data and health effects are wrong. There are no data to support it and it just serves to frighten people. It is just bad government and bad use of resources."

Susan Bullard of EPA's Congressional Liaison Office agrees: "There is no question that there are a lot of toxic chemicals in the air, but we can't say that any of this equates to any particular risk to the public. The public, too, doesn't care about chemical-by-chemical release data. They want to know what it all means." But that is going to take a while to figure out, she adds.

Waxman and his colleagues point out that the Clean Air Act has a toxic chemical provision, Section 112, but EPA has only issued regulations on seven substances (beryllium, mercury, vinyl chloride, asbestos, benzene, radionuclides, and arsenic) and has often reneged on regulating many others. Waxman says his new legislation "will list hazardous air pollutants and mandate that sources of these pollutants use all the technology available to reduce their emissions and protect the public health." It will include provisions to prevent accidental releases of the listed chemicals and require that sources of these chemicals take precautions "so that we can halt the unending series of chemical accidents."

David Hanson

Technologies vital to U.S. defense selected

Concerned that the U.S. is losing its edge in technologies vital for national defense, Congress last September ordered the Department of Defense, in consultation with the Department of Energy, to draw up a Critical Technologies Plan by March 15 each year. The report is to list the 20 technologies deemed "most essential to develop in order to ensure the long-term qualitative superiority of U.S. weapon systems."

Responding to this mandate, DOD has submitted its first annual report to the House and Senate Armed Services committees. The report was released at a Senate hearing in mid-March before the Subcommittee on Defense Industry & Technology, chaired by Sen. Jeff Bingaman (D.-N.M.), initiator of the mandate. In addition, the Pentagon will submit a classified addendum this month amplifying on "sensitive" aspects of the technologies chosen.

The report lists not 20, but 22 technologies. Among those chemically related are preparation of gallium arsenide (GaAs) and other compound semiconductors, high-temperature/high-strength/lightweight composite materials, superconductivity, and biotechnology materials and processing.

At the hearing, Bingaman noted that his panel is responsible for ensuring the "long-term underpinnings of our national security strategy, namely our technology and industrial bases." However, the panel has heard "report after report that those underpinnings [are] eroding."

"A good part of that erosion undoubtedly derives from the inadequate overall level of resources we devote to our technology base," Bingaman adds. "Time after time I found myself in the position where technologies that seemed to be on everyone's list of truly critical technologies were severely underfunded in the DOD request."

For each technology, Congress asked DOD to discuss the reasons for its selection; goals for its development; current funding by DOD, DOE, and other agencies; and its comparative status in the U.S., Soviet Union, and other nations. The report outlines potential contributions by U.S. allies to the technology's development, and progress the private sector may make with its own resources to develop civilian applications. In making up the list, equal consideration was given to process and product technologies, in light of inadequate DOD efforts until now in process and manufacturing R&D.

Report lists 22 crucial technologies

Microelectronic circuits and their fabrication
Preparation of gallium arsenide, other compound semiconductors
Software producibility
Parallel processing computer architectures
Machine intelligence/robotics
Simulation, modeling with computers
Integrated optics (optical memories, signal and data processing)
Fiber optics
Sensitive radars (counter-Stealth technology)
Passive sensors
Automatic target recognition
Phased arrays (radar, underwater acoustic, and others)
Data fusion (machine integration and/or interpretation of data, presentation in convenient form for human operators)
Signature control (reduction of radar, optical, acoustic, or other "signatures" of planes, ships, tanks, other weapons systems)
Computational fluid dynamics (computer simulation)
Air breathing propulsion (for air, land, water propulsion)
High-power microwaves (for weapons use)
Pulsed power (lightweight, compact sources for laser- or microwave-directed energy weapons)
Hypervelocity projectiles
High-temperature/high-strength/lightweight composite materials
Superconductivity
Biotechnology materials and processing

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Protein Folding

Major biotechnology problem
begins to be solved Page 32

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NEWS

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APRIL 10, 1989

News of the Week

- **Scientific community scrambles to explain cold fusion process claimed by two Utah groups.** Page 6
- **As protest continues over settlement of Union Carbide's 1984 chemical disaster in Bhopal, India's high court holds up disbursement of settlement.** Page 7
- **Philadelphia-based SmithKline Beckman and the U.K.'s Beecham Group hold merger discussions.** Page 8
- **University of Chicago researchers find UV radiation at Antarctica increases as ozone hole develops.** Page 8

Business

Top 50 chemicals production hit a record high in 1988, increasing 7.6% to 610 billion lb and putting pressure on existing capacity. **Page 11**

Output of polymers—plastics, synthetic fibers, and synthetic rubber—continued on an upward course, reaching a record 60.4 billion lb last year. **Page 14**

Government

A Carnegie Corp. commission begins effort to examine science advice process, hopes to develop structures, processes useful to political and judicial decision makers. **Page 17**

Department of Energy launches environmental cleanup program that will focus on correcting waste management procedures at its operating facilities. **Page 18**

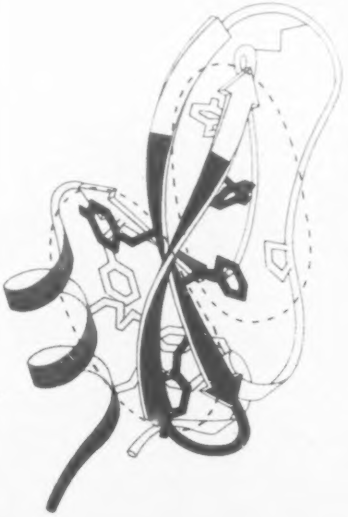
Science/Technology

Indiana-Purdue chemists develop phase-transfer catalysis procedure for the synthesis of α-amino acids. **Page 25**

Stereolithography, a developing photochemical technology, allows computer-generated designs to be made directly into complex plastic parts. **Page 27**

ACS News

ACS books and journals, together with other scientific publications, will be exhibited abroad beginning this summer; professional liability insurance for ACS members is officially offered. **Page 57**



Special Report

As biotechnology unleashes the potential to design and synthesize proteins with functions not currently known, researchers are making inroads in tackling a major unsolved problem in biology and chemistry—how amino acid sequence determines the folding of a polypeptide chain. **Page 32**

Cover: Example of folded protein, phosphoglycerate kinase domain 2. Figure courtesy of Jane S. Richardson

Letters 4

Concentrates

Business 9
Government 16
Science/Technology 20

The Departments

Meetings 61
Awards 68
Newscripts 86

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LETTERS

Chemical substances

SIR: These days, the phrase "chemical substance" has such pejorative connotations that if it were generally realized that table salt is one of those horrid things, a large section of the populace would go on a salt-free diet. To divulge to a tennis partner that you were formerly a chemist is to be immediately held responsible for all the ills that flesh is heir to; the chemical industry is both literally and figuratively in bad odor with the public. A consequence of this disrepute is the widely held idea that all chemicals are dangerous to your health; some are just worse than others. It follows that chemists should be, in general, weak, sickly persons destined for an early grave. But are they?

Large-scale chemical industry and large-scale academic training of chemists in this country are now about 75 years old, or three generations. Laboratory safety measures have changed over this period from none—handling H_2S, SO_2, and cyanides in unventilated rooms—to the mandatory use of high-velocity hoods for the mere evaporation of common solvents. ACS, the federal census, and the chemical companies must have accumulated during this time detailed data on hundreds of thousands of chemists and chemical workers, and insurance companies must possess detailed data on their morbidity and mortality. Yet, to my knowledge, there has never been a large-scale, long-time study of the professional chemist and the chemical worker as a candidate for unusual liver, kidney, heart, or lung damage. Which is worse: a decade of PCBs, but clean air, in Pittsfield; or a decade of mercaptans and smog in Bayonne or Bay City? Who lives longer: a sloppy organic chemist or a Los Angeles cab driver? Who knows?

The Environmental Protection Agency and the Food & Drug Administration are presently buffeted on all sides in their efforts to set reasonable limits on exposure to chemical substances. For new compounds, given the wide physiological disparities in sensitivity that can arise between humans and experimental animals, this is well-nigh impossible; however, there are also continual controversies over substances as common as benzene or carbon tetrachloride. Why do not the agencies listed above, singly or cooperatively, make use of this immense backlog of experimental animals, of the thousands on thousands of researchers who have spent decades evaporating benzene on hot plates, of electrical workers up to the elbows in PCBs, of dry cleaners who inhaled trichloroethylene for 10 or 20 years? Case histories are notoriously unreliable, but taken in thousands they become statistics, which are deemed eminently reliable by government agencies.

It is ironic that Freon 12, that exemplar of industrial safety and physiological harmlessness, should now be shown to threaten the world. It would also be ironic if some of the old familiar compounds that EPA spends so much time and money on were shown, by a large-scale survey of chemists and chemical workers, to be paper tigers. Such a study would probably not reduce anyone's doctor bills, but it might knock a little off the national debt.

John A. Young
Kerrville, Tex.

Offshore minerals

SIR: The article entitled "Prospects for Offshore Mineral Mining Remain in Doubt" (C&EN, Nov. 7, 1988, page 18) was a welcome and informative exposure to marine minerals and some of the underlying geochemistry for our readership. Unfortunately, several inaccuracies managed to make their way into this otherwise highly interesting and timely feature. I have been involved personally in various aspects of marine minerals research for the past 10 years. This work has allowed me to study hydrothermal systems such as that associated with the Loihi submarine volcano in the Hawaiian Archipelago as well as marine ferromanganese deposits from Hawaii and other regions of the Pacific. If I may, I would like to offer a few comments/corrections to the article.

The feature erroneously reports that chimneys on Loihi reach heights of up to 30 meters; the greatest estimates from deep-sea photography and from submersible observations suggest chimney heights up to a maximum of only 3 feet. Furthermore, although recently sampled active low-temperature vents are presently located at 980 and 1260 meters, other vents were sampled at different locations in 1982 during a previous expedition aboard the *USNS De Steiguer*. These vents may no longer be active, but evidence obtained during the latter project suggested that the nontronite deposits, Fe- and Mg-rich aluminosilicates (not insoluble carbonates as indicated in the C&EN article), formed by direct precipitation from warm metal-rich hydro-

Top 50 Chemicals Production Reaches Record High

Output increased 7.6% in 1988 to 610 billion lb; inorganics turned in strongest showing, climbing 8.5%, as organics increased 5.9%

Marc S. Reisch,
C&EN Northeast News Bureau

Continued export growth and heavy domestic demand made 1988 another good year for U.S. chemical output. According to C&EN's annual ranking of the 50 largest-volume chemical products, total production in that group in 1988 increased a dramatic 7.6% from 1987, surpassing the 600 billion lb mark for the first time to 610 billion lb. That growth rate bettered 1987's increase of 6.5% over 1986. In most cases, 1988 production of basic chemicals could not have been much higher without additional capacity on stream than existed during the year.

According to the U.S. Federal Reserve Board, seasonally adjusted capacity utilization for chemicals and products ranged between 86.1 and 89.2% during 1988. As pressure mounted throughout the year on existing capacity because of the strong domestic economy, prices rose dramatically. From December 1987 to December 1988, the producer price index for chemicals and allied products increased 11.5% to reach 121.7 (1982 = 100), according to the U.S. Department of Labor. For the subcategory of industrial chemicals, prices rose even faster: up 16.2% to an index of 114.1.

In one case, rising domestic demand coupled with the loss of Shell Oil's Norco, La., refinery for part of the year conspired both to cap output of ethylene at a lower level than it would otherwise have been and to increase prices dramatically. The explosion at the refinery on May 5 knocked out 2.2 billion lb of capacity that accounted for a full 6% of U.S. ethylene capacity (C&EN, May 16, 1988, page 4). Department of

About the Top 50 list of chemical products

Government data, trade association figures, and industry estimates all go into preparing C&EN's annual list of the Top 50 chemical products, ranked by production volume. The federal government is relied upon most heavily, but when government figures are not available, other sources, primarily trade associations, are used. Industry sources and C&EN estimates are used only when other data are lacking.

Government data are not always accurate—they are only as good as the information that individual companies report. But they are an objective measure of production extending back many years. Therefore, relatively accurate indications of growth can be made on a consistent basis.

At this time of year, C&EN has access only to preliminary reports of production for 1988. When the government and trade associations issue their final reports, the outcome can be changed, sometimes dramatically. As a result, the production figures for earlier years that appear in the table on page 12 are different in some cases from those published in last year's Top 50 article. The final reports also can affect the rankings of chemicals. For the table published on page 12, the 1987 ranking of only one chemical, potash, is different from last year's listing (C&EN, April 11, 1988, page 31). But production revisions affected the 1986 ranking of 16 chemicals in the table appearing last year.

The list itself covers production figures for the U.S. and includes chemicals produced for export. Candidates for the list include all basic, intermediate, and chemically homogeneous finished products. These range from chemical building blocks like ethylene and propylene to downstream products like vinyl acetate and ethylene glycol.

The roster also includes basic inorganic chemicals but does not include what C&EN considers to be minerals, such as salt, gypsum, and sulfur. Lime is included because it is processed and has many chemical and industrial applications. Refractory (dead burned) dolomite is excluded in the calculations of lime production.

In the organics list, such petrochemical feedstocks as ethane, butane, and propane are excluded arbitrarily because they are considered to be products of oil companies and because they have many nonchemical uses.

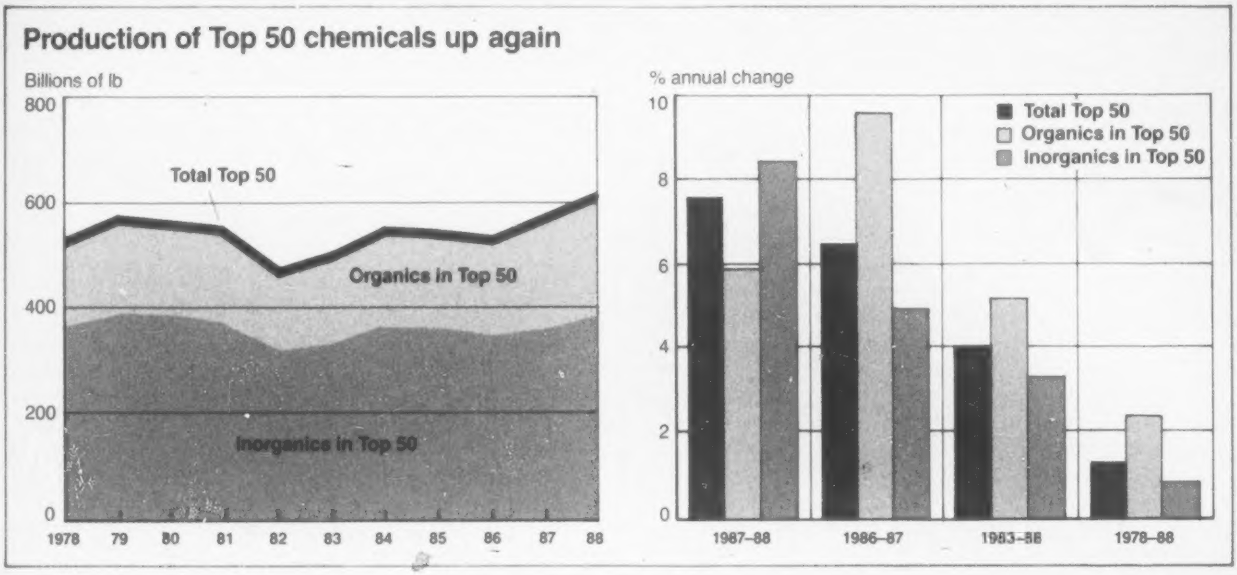
There are other gray areas besides lime and petrochemical feedstocks. For example, the basic aromatics—benzene, toluene, and xylene—are included. Admittedly, this makes the list less pure chemically.

Production figures are published by the government and trade associations in a variety of units—pounds, tons, cubic feet, gallons, metric tons. To provide an accurate ranking and to make comparison of production volumes easier, C&EN lists production not only in common units but converted to pounds as well.

Top 50 chemicals production totaled about 610 billion lb in 1988

Rank			Billions of lb		Common units[b]		Average annual growth			
1988	1987[a]		1988	1987	1988	1987	1987–88	1986–87	1983–88	1978–88
1	1	**Sulfuric acid**	85.56	77.50	42,779 tt	38,750 tt	10.4%	5.2%	2.7%	0.3%
2	2	**Nitrogen**	52.10	47.39	719 bcf	654 bcf	9.9	−2.5	5.1	6.3
3	5	**Oxygen**	37.09	32.28	448 bcf	390 bcf	14.9	−2.3	5.3	0.5
4	3	**Ethylene**	36.56	34.99	36,562 mp	34,992 mp	4.5	6.5	5.0	3.5
5	4	**Ammonia**	33.89	32.32	16,946 tt	16,161 tt	4.9	15.4	4.0	−0.1
6	6	**Lime**[c]	32.34	30.36	16,169 tt	15,182 tt	6.5	2.3	1.7	−2.3
7	7	**Sodium hydroxide**	23.97	23.04	11,983 tt	11,518 tt	4.0	7.7	3.2	0.6
8	9	**Phosphoric acid**	23.43	20.95	11,717 tt	10,473 tt	11.9	13.8	3.7	2.0
9	8	**Chlorine**	22.66	21.96	11,329 tt	10,980 tt	3.2	5.2	2.6	0.2
10	10	**Propylene**	19.97	18.53	19,966 mp	18,527 mp	7.8	12.1	7.4	4.4
11	11	**Sodium carbonate**[d]	19.10	17.78	9,550 tt	8,891 tt	7.4	5.4	2.4	1.4
12	13	**Nitric acid**	15.78	14.20	7,889 tt	7,102 tt	11.1	8.2	2.5	−0.1
13	12	**Urea**[e]	15.76	14.88	7,878 tt	7,441 tt	5.9	23.4	5.6	2.3
14	15	**Ammonium nitrate**[f]	14.38	12.83	7,188 tt	6,416 tt	12.0	15.5	2.9	0
15	14	**Ethylene dichloride**	13.65	13.81	13,652 mp	13,805 mp	−1.1	6.7	3.5	2.2
16	16	**Benzene**	11.84	11.67	1,608 mg	1,585 mg	1.5	16.4	5.5	0.8
17	18	**Ethylbenzene**	9.94	9.41	9,936 mp	9,409 mp	5.6	4.3	4.8	1.7
18	20	**Terephthalic acid**[g]	9.60	8.11	9,604 mp	8,110 mp	18.4	5.5	11.3	4.9
19	17	**Carbon dioxide**[h]	9.38	9.86	4,691 tt	4,932 tt	−4.9	1.0	3.7	4.0
20	19	**Vinyl chloride**	9.06	8.23	9,056 mp	8,230 mp	10.0	−2.5	5.7	2.7
21	21	**Styrene**	8.59	8.09	8,588 mp	8,090 mp	6.2	2.6	4.8	1.8
22	22	**Methanol**	7.34	7.29	7,343 mp	7,292 mp	0.7	1.2	−1.7	1.3
23	24	**Formaldehyde**[i]	6.73	6.08	6,730 mp	6,077 mp	10.7	9.5	4.3	0.5
24	23	**Toluene**[j]	6.47	6.73	892 mg	928 mg	−3.9	51.9	2.7	−1.7
25	25	**Xylene**	5.93	5.72	824 mg	795 mg	3.6	27.6	2.6	−0.3
26	28	**Hydrochloric acid**	5.87	4.99	2,933 tt	2,495 tt	17.6	3.4	3.9	0.5
27	27	***p*-Xylene**	5.60	5.15	5,598 mp	5,152 mp	8.7	2.3	6.4	4.8
28	26	**Ethylene oxide**	5.37	5.62	5,365 mp	5,623 mp	−4.6	3.6	−0.6	0.5
29	29	**Ethylene glycol**	4.90	4.52	4,899 mp	4,515 mp	8.5	−5.4	2.1	2.3
30	31	**Cumene**	4.80	4.15	4,800 mp	4,151 mp	15.6	10.8	7.5	3.6
31	32	**Methyl *tert*-butyl ether**[k]	4.68	3.37	4,684 mp	3,372 mp	38.9	−0.1	41.0	na
32	30	**Ammonium sulfate**	4.67	4.37	2,337 tt	2,183 tt	7.1	4.7	3.6	−0.5
33	33	**Phenol**[l]	3.53	3.24	3,528 mp	3,241 mp	8.9	4.0	6.0	2.8
34	36	**Potash**[m]	3.35	2.78	1,520 tmt	1,262 tmt	20.4	5.0	1.2	−3.9
35	35	**Butadiene**[n]	3.19	3.00	3,194 mp	3,002 mp	6.4	15.8	6.3	−1.0
36	34	**Acetic acid**	3.16	3.23	3,164 mp	3,227 mp	−2.0	18.3	2.4	1.3
37	38	**Propylene oxide**	3.11	2.61	3,110 mp	2,608 mp	19.2	5.2	10.8	4.3
38	37	**Carbon black**	2.92	2.72	2,916 mp	2,724 mp	7.0	5.4	3.2	−1.4
39	41	**Aluminum sulfate**	2.59	2.45	1,297 tt	1,223 tt	6.1	0.1	3.3	−0.1
40	39	**Acrylonitrile**	2.58	2.55	2,576 mp	2,551 mp	1.0	16.9	3.7	3.9
41	40	**Vinyl acetate**	2.56	2.51	2,561 mp	2,505 mp	2.2	46.5	−5.5	4.2
42	42	**Cyclohexane**	2.32	2.25	2,319 mp	2,250 mp	3.1	8.6	7.0	−0.1
43	43	**Acetone**	2.29	2.08	2,285 mp	2,082 mp	9.8	7.5	4.2	−1.0
44	44	**Titanium dioxide**	2.04	1.90	1,021 tt	952 tt	7.2	2.3	6.2	3.8
45	46	**Sodium sulfate**[o]	1.69	1.61	845 tt	805 tt	5.0	3.9	−0.2	0.4
46	44	**Sodium silicate**	1.64	1.90	821 tt	952 tt	−13.8	21.1	2.4	−0.1
47	47	**Adipic acid**	1.59	1.57	1,588 mp	1,572 mp	1.0	3.3	4.4	−0.2
48	49	**Isopropyl alcohol**	1.42	1.31	1,418 mp	1,313 mp	8.0	0.9	3.2	−2.0
49	48	**Calcium chloride**[p]	1.31	1.55	657 tt	773 tt	−15.0	−0.9	−5.2	−4.4
50	50	**Caprolactam**	1.26	1.16	1,261 mp	1,161 mp	8.6	4.7	5.2	3.2
TOTAL ORGANICS			213.79	201.87			5.9%	9.6%	5.2%	2.4%
TOTAL INORGANICS			395.76	364.76			8.5%	4.9%	3.3%	0.8%
GRAND TOTAL			609.55	566.63			7.6%	6.5%	4.0%	1.3%

a Revised. b tt = thousands of tons, bcf = billions of cubic feet, mp = millions of pounds, mg = millions of gallons, tmt = thousands of metric tons. c Except refractory dolomite. d Natural and synthetic. e 100% basis. f Original solution. g Includes both acid and ester without double counting. h Liquid and solid only. i 37% by weight. j All grades. k Production data for earlier years unavailable. l Synthetic only. m K_2O basis. n Rubber grade. o High and low purity. p Solid and liquid. na = not available.



Production of Top 50 chemicals up again

Labor figures show that ethylene prices rose 69% between December 1987 and December 1988 to an index of 178.8.

Ethylene was not the only commodity under capacity restrictions. Sodium hydroxide producers, for instance, operated at record levels throughout 1988 (C&EN, Aug. 8, 1988, page 20). As supplies of sodium hydroxide tightened, prices climbed. During the year, sodium hydroxide prices increased 49% to an index of 85.9, according to the Department of Labor.

The low U.S. dollar relative to most foreign currencies at least kept U.S. chemical producers competitive with overseas manufacturers in most cases. However, because of the increase in domestic prices, many of the chemical bargains that drove production for export in 1987 did not exist in 1988. On the domestic front, demand for chemicals in housing and the auto market continued strong as these industries turned increasingly to chemical-based adhesives in place of metal fasteners, to plastics in place of steel auto body components, or to vinyl siding for housing in place of wood. Fertilizer demand was good despite drought conditions in most of the country, as fertilizer purchases and application were made in advance of the drought's effects.

Among the largest-volume chemicals produced in the U.S., sulfuric acid remained on top with total production of 85.6 billion lb, a 10% increase from 1987. Nitrogen continued to rank a distant second, with production at 52.1 billion lb, up 9.9% from 1987. That was a better showing than in 1987, when production declined 2.5%.

Organic chemicals, comprising some 35% of the Top 50, made a good showing in 1988 but growth did not do so well as it did in 1987. Production of those substances increased 5.9% in 1988 compared with a 9.6% year-to-year increase in 1987. Between 1983 and 1988, production of organic chemicals among the Top 50 increased an average of 5.2% a year. Over the long term, however, their output has grown at a much slower pace. Between 1978 and 1988, output of organic chemicals among the Top 50 grew at a compound annual rate of only 2.4% a year.

However, the inorganic segment of the Top 50 increased markedly in 1988. Production grew 8.5%, following a 4.9% increase in 1987. Within this category, production grew for major fertilizer chemicals—including phosphoric acid, up 12%; urea, up 5.9%; and potash, up 20%. Other big-volume inorganics also showed improvements. Hydrochloric acid production increased almost 18%, and ammonium nitrate production increased 12%.

Of the Top 50 chemicals, production of 43 of them increased in 1988. By contrast, production of 44 increased in 1987. Total production of the Top 50 chemicals, at 610 billion lb, was up 7.6% from 1987 and exceeded the historical high of 575 billion lb in 1979 by 6.1%. The 1988 production level was 32% higher than the decade-low level of 464 billion lb registered in 1982.

For the Top 50 group, composite output increased at a compound annual rate of 4.0% between 1983 and 1988. Indicative of long-term growth, Top 50 production grew at an average annual rate of 1.3% between 1978 and 1988.

As a group, inorganic chemicals outperformed the organics. Showing the largest production gain on the inorganics side was potash, up 20% from 1987 to 3.35 billion lb. The gain pushed potash from 36th place in 1987 to 34th place in the 1988 rankings.

Next in terms of percentage gains among the inorganics was hydrochloric acid, up almost 18% to 5.87 billion lb. The gain placed the chemical 26th in the 1988 list compared with its 28th place showing in the 1987 rankings.

Also showing very good production increases in 1988 were oxygen, up 15% to 37.09 billion lb following a 2.3% decline in the previous year; and ammonium nitrate, up 12% to 14.38 billion lb, following a 16% rise in the previous year.

Other large-volume inorganic chemicals that had large increases in production last year were phosphoric acid, up 12% to 23.43 billion lb following a 14% increase the year before; and nitric acid, up 11% to 15.78 billion lb following an 8.2% increase the year before.

But although the inorganics as a group registered the largest percentage increases in 1988, a few chemicals in the group showed the largest annual decline in the Top 50 list. Calcium chloride production dipped 15% last year to 1.31 billion lb, following a 0.9% decline a year ago. Sodium silicate production registered a remarkable 14% decline in 1988 to 1.64 billion lb, following close on the 21% increase in production for 1987. Carbon dioxide production also slipped 4.9% in 1988 to 9.38 billion lb following a 1.0% rise in 1987.

For organic chemicals, 1988 production growth was led by terephthalic acid, up 18% from 1987 to 9.60 billion lb. As a result, terephthalic acid moved from 20th place in the 1987 ranking to 18th place in the 1988 list. Cumene also showed good growth in 1988, up 16% to 4.80 billion lb. As a result, cumene also improved its position in the rankings and moved from 31st in the 1987 listing to 30th in the 1988 list.

On the downside of production, leading the products with the largest individual decreases over the five-year period was calcium chloride, whose output fell at an annual compound rate of 5.2%. Other chemicals registering production declines over the five-year period were methanol, down 1.7%, and ethylene oxide, down 0.6%.

Looking at growth over the past 10 years, 32 of the Top 50 chemicals have recorded overall production increases. The best long-term performer has been nitrogen, whose output grew at an annual compound rate of 6.3% during the period. Production of terephthalic acid also grew at a good rate of 4.9%. Other chemicals with sizable growth rates were *p*-xylene, up 4.8%; propylene, up 4.4%; and propylene oxide, up 4.3%. Calcium chloride registered the largest average annual rate of decline over the past 10 years. Its output has fallen at a compound annual rate of 4.4%. □

Polymer output rises for sixth consecutive year

Overall production of plastics, synthetic fibers, and synthetic rubber polymers reached a record high of 60.4 billion lb in 1988. The growth marked the sixth consecutive annual increase for the product group, lifting the output total 6.0% above the 1987 record.

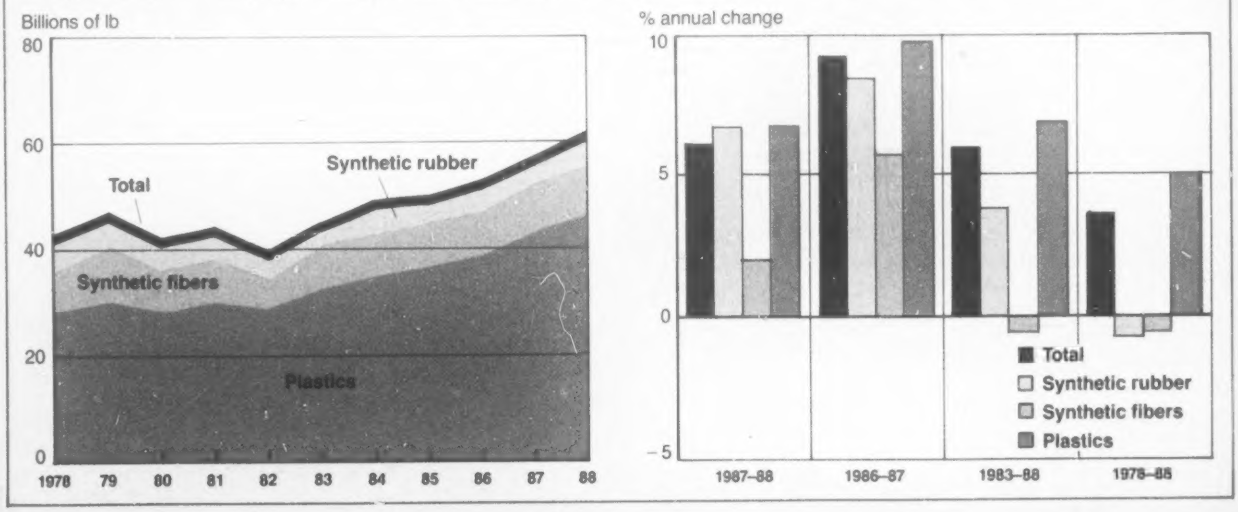
Plastics, which account for more than three quarters of the polymer group production totals, continued excellent growth in 1988. Production was up 6.7% from 1987—a respectable showing, but not so strong as the 9.8% annual growth in 1987.

The strongest growth among plastics was registered by the thermoplastic resins, whose output rose 6.9% last year. Of such resins, production of polypropylene continued to show the highest growth, up 9.4%, followed by low-density polyethylene with 8.3%, polystyrene with 7.3%, high-density polyethylene with 5.1%, and polyvinyl chloride and copolymers with 4.8%.

By comparison, output of thermosetting resins grew 5.3% in 1988. Unmodified epoxies exhibited the most remarkable growth, up 14% from 1987 following an 8.8% increase in 1987. Among other thermosetting resins, production of phenol and other tar acid resins grew 6.8% in 1988; urea resins, 3.1%; and unsaturated polyesters, 2.6%.

Melamine resins output, which showed such spectacular growth in 1987, declined in 1988. Melamine resin production dropped to 207 million lb last year, a 2.4% decline from the previous year when output of 212 million lb was almost 23% ahead of production levels in 1986.

For the five-year period 1983–88,


Output of plastics, synthetic fibers, and synthetic rubber continued to climb in 1988

Total polymer output exceeded 60 billion lb last year

	Billions of lb		Common units					Average annual growth			
	1988	1987	1988	1987	1986	1983	1978	1987–88	1986–87	1983–88	1978–88
PLASTICS (millions of lb)											
Thermosetting resins	**6.60**	**6.27**	**6,597**	**6,265**	**5,834**	**5,254**	**4,449**	**5.3%**	**7.4%**	**4.7%**	**4.0%**
Phenol and other tar acid resins	3.07	2.87	3,066	2,870	2,721	2,484	1,617	6.8	5.5	4.3	6.6
Urea resins	1.43	1.38	1,425	1,382	1,271	1,172	1,122	3.1	8.7	4.0	2.4
Polyesters (unsaturated)	1.40	1.37	1,404	1,368	1,271	1,084	1,209	2.6	7.6	5.3	1.5
Epoxies (unmodified)	0.50	0.43	495	433	398	334	299	14.3	8.8	8.2	5.2
Melamine resins	0.21	0.21	207	212	173	180	202	−2.4	22.5	2.8	0.2
Thermoplastic resins	**39.55**	**36.99**	**39,549**	**36,992**	**33,569**	**27,799**	**23,932**	**6.9%**	**10.2%**	**7.3%**	**5.2%**
Low-density polyethylene	10.40	9.60	10,398	9,599	8,888	8,041	7,111	8.3	8.0	5.3	3.9
PVC and copolymers	8.35	7.97	8,350	7,971	7,256	6,066	5,723	4.8	9.9	6.6	3.8
High-density polyethylene	8.40	8.00	8,399	7,995	7,171	5,691	4,201	5.1	11.5	8.1	7.2
Polystyrene[a]	5.13	4.78	5,130	4,780	4,442	3,567	3,823	7.3	7.6	7.5	3.0
Polypropylene	7.27	6.65	7,272	6,647	5,812	4,434	3,074	9.4	14.4	10.4	9.0
TOTAL[b]	**46.15**	**43.26**	**46,146**	**43,257**	**39,403**	**33,053**	**28,381**	**6.7%**	**9.8%**	**6.9%**	**5.0%**
SYNTHETIC FIBERS (millions of lb)											
Cellulosics	**0.61**	**0.61**	**614**	**605**	**619**	**640**	**905**	**1.5%**	**−2.3%**	**−0.8%**	**−3.8%**
Rayon	0.40	0.41	400	414	404	411	597	−3.4	2.5	−0.5	−3.9
Acetate[c]	0.21	0.19	214	191	215	229	308	12.0	−11.2	−1.3	−3.6
Noncellulosics[b]	**8.49**	**8.32**	**8,489**	**8,316**	**7,828**	**8,701**	**8,691**	**2.1%**	**6.2%**	**−0.5%**	**−0.2%**
Polyester[d]	3.68	3.54	3,679	3,541	3,305	3,543	3,800	3.9	7.1	0.8	−0.3
Nylon	2.67	2.69	2,666	2,689	2,514	2,418	2,550	−0.9	7.0	2.0	0.4
Olefin[e]	1.56	1.49	1,556	1,494	1,393	902	692	4.1	7.3	11.5	8.4
Acrylic[f]	0.59	0.59	588	592	616	671	726	−0.7	−3.9	−2.6	−2.1
TOTAL[b]	**9.10**	**8.92**	**9,103**	**8,921**	**8,447**	**9,341**	**9,596**	**2.0%**	**5.6%**	**−0.5%**	**−0.5%**
SYNTHETIC RUBBER (thousands of metric tons)											
Styrene-butadiene[g]	1.98	1.87	900	850	792	904	1,395	5.9	7.3	−0.1	−4.3
Polybutadiene	0.90	0.82	407	371	336	333	378	9.7	10.4	4.1	0.7
Ethylene-propylene	0.58	0.56	263	254	230	175	174	3.5	10.4	8.5	4.2
Nitrile	0.17	0.15	76	69	59	55	73	10.1	16.9	6.7	0.4
Other[h]	1.50	1.41	679	638	596	468	454	6.4	7.0	7.7	4.1
TOTAL[b]	**5.13**	**4.81**	**2,325**	**2,182**	**2,013**	**1,935**	**2,474**	**6.6%**	**8.4%**	**3.7%**	**−0.6%**

[a] No longer includes acrylonitrile-butadiene-styrene or styrene-acrylonitrile resins; historical data are restated. [b] Totals are for those products listed. Totals may not add because of rounding. [c] Includes diacetate and triacetate yarn, but does not include cigarette tow. Beginning with 1985, includes rayon yarn. [d] Excludes aramid after 1982. [e] Includes olefin film, olefin fiber, spun-bonded polypropylene, and vinyon. [f] Includes modacrylic. [g] Excludes high-styrene latex. [h] Beginning with 1985, includes neoprene; historical data are restated. Also includes butyl; polyisoprene; chlorosulfonated polyethylene; polyisobutylene; and acrylo, fluoro, and silicone elastomers. **Sources:** Society of the Plastics Industry, Textile Economics Bureau, Rubber Manufacturers Association

the plastics segment grew at an annual compound rate of 6.9%. For the 10-year period between 1978 and 1988, plastics grew at an annual compound rate of 5.0%.

Output of synthetic rubber, another polymers segment, increased 6.6% in 1988. Production of 5.1 billion lb last year was the best showing from the category since 1979, when production reached 5.6 billion lb. Output is still running 9.8% below the decade high reached in 1979.

All segments of the synthetic rubber category registered increases in production in 1988. Just as it did in 1987, nitrile rubber registered the largest increase, with production rising 10% last year, following its spectacular 1987 growth of 17%. Polybutadiene output grew 9.7% last year.

Other categories did less well but still grew. Styrene-butadiene rubber production increased 5.9% in 1988, followed by ethylene propylene output, up 3.5%.

Over the past five years, the synthetic rubber category has grown at a compound annual rate of only 3.7%. For the past 10 years, production has actually declined at an average annual rate of 0.6%.

For another polymers group, synthetic fibers, the respectable performance put in for 1987 was not repeated for 1988. Although the yearly production growth in 1987 was 5.6%, growth last year slowed to just 2.0%. Though the volume of imported textiles has stabilized, U.S. textile producers have yet to regain the share of market they held only a few years ago.

The noncellulosics group, which accounts for more than 90% of synthetic fiber production in the U.S., grew 2.1% in 1988. The growth leader was olefin, up 4.1% compared with the year-earlier level, followed by polyester, up 3.9%. Nylon and acrylic production declined marginally, down 0.9% and 0.7%, respectively.

The cellulosics group recorded a marginal gain of 1.5% in 1988 following the 2.3% decline in 1987. Rayon production slipped 3.4% as a result of a temporary shutdown of the Avtex fiber complex in Front Royal, Va. Acetate production increased 12% as replacements for triacetate fiber, withdrawn from production a few years ago, have now come into the market.

Marc Reisch

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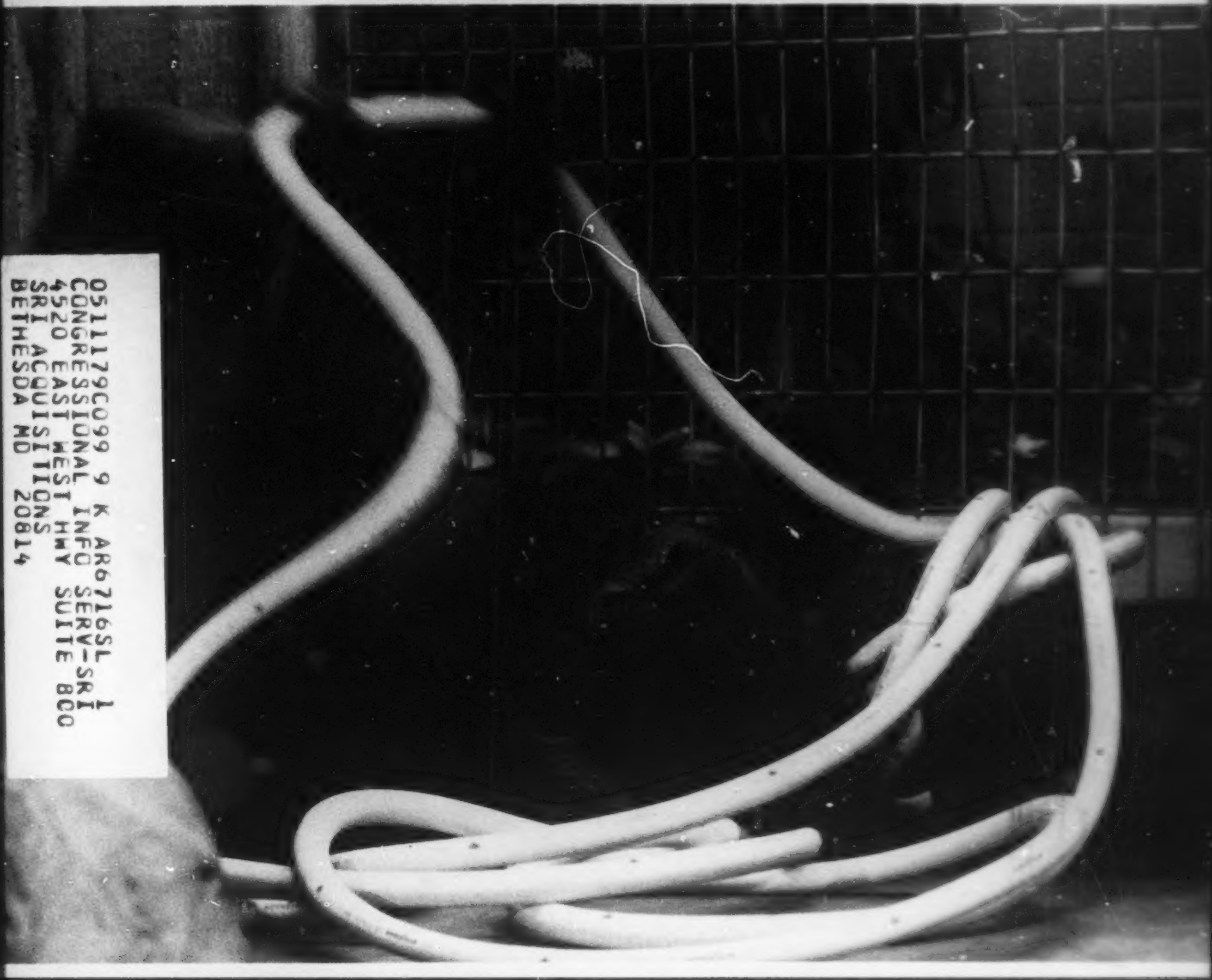
APRIL 17, 1989

CHEMICAL & ENGINEERING NEWS



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RUBBER CHEMICALS

Producers strive to meet tougher performance demands Page 25

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CHEMICAL & ENGINEERING NEWS

APRIL 17, 1989

News of the Week

- **Utah's Pons and others discuss latest findings in nuclear fusion research at ACS session.** Page 4
- **Berkeley chemists develop biosynthetic technique for protein modification.** Page 5
- **ACS Dallas meeting features sessions on nuclear fusion and biotechnology.** Page 6
- **CAS agrees to joint software pact with Telesystemes Questel, Hampden Data Services Ltd.** Page 7
- **National Research Council panel finds NSF manpower surveys flawed, suggests improvements.** Page 7
- **Alaskan oil spill sets off doubts about competence and credibility of federal agencies, oil industry.** Page 8
- **Robert Maxwell, British media baron, signs protocol for joint science database development with Soviet technical information institute.** Page 8

Cover: Zoo gorilla plays with Goodyear's multipurpose rubber hose, tradenamed Gorilla for its strength, which was designed for agriculture, mining, and construction industries

Letters 2

Concentrates
Business 11
Government 17
Science/Technology 20

The Departments
Software/Database Update 24
New Products 53
Meetings 63
Newscripts 84

Business

British Petroleum's BP Chemicals attributes the remarkable progress it has made since 1984 to restructuring, cutbacks, and product choice. **Page 13**

Government

Small Department of Energy division that specializes in high-risk, innovative research counts cold fusion experiments among projects it has funded. **Page 18**

Science/Technology

Synthesis of unusual metal complexes by Berkeley chemists sheds new light on the interactions of metals with organic compounds. **Page 21**

New technique, pulse oriented gel electrophoresis, produces first images of individual DNA molecules. **Page 23**

Books

"**Natural Obsessions: The Search for the Oncogene,**" a welcome addition to popular literature of science, explores day-to-day work in one cancer research lab. **Page 57**

ACS News

ACS urges Congress to increase funding for energy research, asks EPA to allow labs to treat some chemical waste in-house. **Page 60**

Product Report

Market for rubber-processing chemicals has picked up in the past two years and is demanding higher performance chemicals. Page 25

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LETTERS

Radon monitoring

SIR: I would like to commend David Hanson (C&EN, Feb. 6, page 7) on his fine, comprehensive presentation of the radon monitoring/control issue. A major point of new information was not mentioned by Hanson, however. Title III—Indoor Radon Abatement, an Amendment of the Toxic Substances Control Act was passed by both houses of Congress and signed by President Reagan in October 1988. "The bill now sets as a long-term national goal the reduction of radon in buildings to the level of the outside air" or to "background levels of 0.2 picocuries per liter." (*Congressional Record-House,* Oct. 5, 1988, pages H9637 and H9640).

One of the main purposes of the legislation is to supply individual states with money to begin extensive programs of radon testing, and to train radon testing and mitigation personnel. This amendment has significant impact on mitigation, perceived health effects, and screening measurements of indoor radon.

Mitigation down to 4 pCi per L (the present Environmental Protection Agency guideline) is well within the capabilities of current contractors and techniques. Mitigation to ambient values may or may not be possible using existing technology. Mitigation of radon in houses presently costs about $300 to $5000 for various engineering modifications; decreasing radon to more than an order of magnitude less than 4 pCi per L may cost up to an order of magnitude more.

Potential deleterious health effects of radon have not been well documented experimentally below 4 pCi per L. Further research will be necessary to ascertain the true relationship of low concentrations of radon in air to cancer in humans.

Radon levels in indoor air fluctuate drastically with changes in soil moisture, barometric pressure, outside wind movement, outdoor/indoor temperature differences (the stack effect), and different building conditions during testing. Therefore, defining the true annual average concentrations in buildings may be difficult. The most commonly used inexpensive measurement techniques (charcoal cannister; track-etch) suffer from uncertainties of up to ±25% (two standard deviations, at the 90% confidence level) for side-by-side duplicate analyses, and uncertainties up to ±50% for track-etch to ±90% for charcoal cannisters (90% confidence level) in projecting annual exposures from a single measurement (personal communication from D. G. Mose, George Mason University). Therefore, defining the true annual radon concentrations in buildings will be difficult and expensive under the new guideline.

The amendment strongly recommends (but does not mandate) as a national goal mitigation of all homes and buildings to the lowest feasible level below 4 pCi per L. EPA has been directed to aggressively promulgate the newly recommended ambient indoor radon guideline and emphasize the hazard of radon concentrations well below the 4 pCi per L former guideline. However, such federal guidelines often carry the weight of law. As tenants sue building owners over elevated radon exposure, state-of-the-art and best standard practices arguments in civil suits may eventually require building owners to mitigate radon to ambient concentrations.

E. Kent Sprague
McCrone Environmental Services Inc.
Norcross, Ga.

Fluoridation of water

Sir: The letter by Surgeon General C. Everett Koop on fluoridation of water (C&EN, Nov. 28, 1988, page 2) and subsequent letters to the editor illustrate the apparent flexibility of the scientific method in connection with a political goal. The letters accurately point out the need for more stringent criteria, more open discussion among scientists concerning the quality of the scientific data, as well as the limitations of the scientific method before conclusions reach the popular media and political leaders. Perhaps the best example of public policy built on a foundation of emotion and political goals rather than rigorous science is that of environmental tobacco smoke and the alleged health effects on the nonsmoker. Since the Surgeon General's report of the health consequences of involuntary smoking, which concluded that "involuntary smoking is a cause of disease including lung cancer in health of nonsmokers" (which was not adequately supported by the evidence presented in the body of the report), the statistically estimated death toll attributed to environmental tobacco smoke set forth in published reports has escalated from 5000 [*Environ. Int.*, **11,** 3 (1985)] to 46,000 [*Environ. Int.*, **14,** 249 (1988)]. Although these reports were peer reviewed, they suffer from many of the limitations cited in the article by Alvan R. Feinstein in *Science* [**242,** 1257 (1988)] regarding the need for improved methods in epidemiology.

The unsubstantiated number of

PRODUCT REPORT

Employee at Goodyear's radial passenger car tire plant in Union City, Tenn., checks high-performance tire on production line

Rubber Chemicals Face More Demanding Market

Bruce F. Greek, C&EN Houston

Demand for rubber-processing chemicals has surged during the past two years. The upswing resulted from a global rise in demand for various kinds of tires and fabricated rubber products. Future growth for these chemicals will follow growth of rubber products use because unit consumption of chemicals in rubber is expected to change very little during the next few years.

Rubber-processing chemicals play a key role in the manufacture of rubber products because they provide desirable properties to commercial rubber products. They aid in rubber vulcanization, protect polymer chains, and make processing of elastomers easier and less costly. Seldom is a rubber product fabricated without the help of such chemicals.

Output of U.S. rubber-processing chemicals this year is expected to top 400 million lb. Production in 1988 was close to 400 million lb. Although expected to increase, output of rubber-processing chemicals won't grow so much as in 1987 nor so much as in 1986 when the current boom in rubber chemicals began.

Capacity to make these chemicals is operating full out. Minor debottlenecking and process-efficiency improvements are the sources of any increases in capacity; no new plants or units have been announced this year.

Rubber-processing chemicals usually are defined as those that react with the rubber. Some may be part of the vulcanization process, and are known as accelerators or retarders because of the way they affect that process. Others, called antidegradants or age resisters, decompose to prevent a degradative reaction of elastomers with oxygen or to minimize effects of light and heat on polymers. Yet other chemicals are used to break polymer chains, making processing quicker and easier and otherwise aiding the fabrication process.

Some chemicals that rarely react with the elastomer are used in compounding rubber for fabrication.

Rubber-processing chemicals at a glance

Most finished rubber products consist of elastomers and a host of additives. The additives are used to provide the best possible cost/performance for the products. Many complex organic chemicals—rubber-processing chemicals—aid the vulcanization process; reduce attack on the elastomer polymer by a combination of oxygen, ozone, and light; and make the fabrication of rubber products easier

U.S. production: (1987) 382 million lb

U.S. merchant sales: (1987) quantity—289 million lb, value—$359 million

Producers: More than 20 in U.S.

Suppliers: More than 50 in U.S. of formulated products for rubber compounding

Compounds: Several hundred compounds are known to have use in rubber processing, but fewer than 200 are of commercial significance. Examples of significant compound groups: benzothiozoles, *p*-phenylenediamines, phosphites, polyphenols, and dithiocarbamic acid derivatives

In the rubber industry, however, they are considered to be outside the group known as rubber-processing chemicals. Some examples are carbon black, titanium dioxide, silica, and waxes. Carbon blacks and many inorganic materials are used as reinforcements, fillers, and colorants.

Sulfur is especially important to the vulcanization process, but it, too, generally is excluded from the group referred to as rubber-processing chemicals. Other chemicals also are used in different kinds of vulcanization or curing processes. Large quantities of fabrics made of synthetic or natural fibers, glass, and metals also may be used in fabricated rubber products.

In 1987, more than 20 companies produced a total of 382 million lb of rubber-processing chemicals, according to the U.S. International Trade Commission (ITC). Output was up 58 million lb, or 18% from 324 million lb in 1986. The ITC data are questionable, according to several company officials, who point out that many rubber-processing chemicals have applications in other industries. That situation leads to potentially subjective allocation by end-uses and to the high growth rates. Producers consequently put production growth of rubber-processing chemicals between 4 and 7% annually for 1986 and 1987.

Although U.S. demand for rubber has increased modestly during the past two years, world demand has increased more rapidly, causing the consumption of rubber-processing chemicals to rise globally. The rise in global demand has spurred exports of U.S. rubber-processing chemicals. Until production became limited by available capacity, U.S. exports also were spurred by the decline in the value of the dollar relative to many other currencies. Lack of expected sales of rubber-processing chemicals produced in East bloc countries, despite construction of new plants in these countries to make these chemicals, has been another factor in rising exports. Expansion of demand for rubber products in East bloc countries apparently has absorbed output from the new capacity there.

Nearly all plants making rubber-processing chemicals in noncommunist countries currently are operating at capacity. The few expansions of capacity now under way are minor, although they are larger than debottlenecking projects. Thus tight supply, limited increases in production, and some additional selling price increases will make up the business during 1989, say some industry sources. Trade in these chemicals will increase faster than production because of efforts of consumers in various parts of the world to get supplies of chemicals they need. No real shortage of acceptable chemicals is expected, however, because capacity to fabricate rubber products also is running nearly full out.

Additional capacity to make rubber-processing chemicals likely will be needed later on. Despite possibilities that economic slowdowns will occur, significant increases in rubber consumption are forecast. For example, consumption of both synthetic and natural rubber in noncommunist countries will increase 11% between 1988 and 1993, reaching 12.1 million metric tons, according to the latest study of the International Institute of Synthetic Rubber Producers (IISRP). Consumption of synthetic rubber will grow faster than that of natural rubber. Demand for most types of synthetic rubber will increase during the next five years, with that for ethylene-propylene-diene rubbers predicted to have the largest growth.

Annual consumption of all kinds of rubber will grow slowly, suggesting that small debottlenecking

Production of rubber-processing chemicals on the upswing

	CYCLICS								ACYCLICS			
				Antidegradants[b]								
	Accelerators[a]											
Millions of lb	Thiazoles	Others	Total	Amino compounds	Phenolics and phosphites	Total	All others	Total cyclics	Accelerators[a]	Others	Total acyclics	Grand total
1983	62.9	5.1	68.0	105.6	63.4	169.0	9.1	246.1	8.8	37.7	46.5	**292.5**
1984	80.3	9.3	89.6	98.0	62.7	160.7	9.5	259.8	8.8	19.0	27.8	**287.6**
1985	63.9	5.2	69.1	100.2	59.3	159.5	8.6	237.2	6.9	16.1	23.0	**260.2**
1986	52.1	4.3	56.4	112.6	67.8	181.3	59.1	296.8	na	na	27.3	**324.1**
1987	80.9	4.2	85.1	123.2	80.5	203.7	65.6	354.4	5.3	22.4	27.7	**382.0**

a Includes activators and vulcanizing agents. b Includes antioxidants, antiozonants, and stabilizers. na = not available. **Source:** International Trade Commission

Special chemicals are essential to rubber compounding

Small amounts of rubber-processing chemicals provide large benefits in physical properties of finished rubber products. Rubber-processing chemicals strongly affect the degree and time of the vulcanization of rubbers; influence greatly the flexibility of the final fabricated products; help elastomers resist breaking up from attack by oxygen, ozone, light, and heat; and reduce the harmful effects of hysteresis or heat buildup. They are essential to providing rubber goods that perform well at low cost.

Rubber-processing chemicals of greatest commercial value are those used in rubber processing prior to fabrication and also during fabrication itself to provide many desirable properties. Other materials used in compounding rubber for subsequent fabrication are vulcanizing agents, most of which include a sulfur atom or are peroxides, metallic oxides, or urethane-type compounds; carbon blacks (particularly used to give abrasion resistance, tensile strength, and tear resistance); and fillers such as clays, silicas, and calcium carbonate. Other chemicals involved in elastomer production are catalysts for polymerization, controls for molecular weight, and antioxidants to stabilize raw polymers.

Some rubber chemicals are multifunctional in providing desired properties to the fabricated rubber products and in aiding the rubber compounding process. However, most have a single use. Often more than one compound may be used to cause an action during compounding or curing of rubber or to give a specific property to a final product.

Not all functions of rubber chemicals are required in all fabricated forms, but the major functional types are added to most compounds. The quantities used may vary quite widely, depending on the desired performance of the products. The commercially significant functions of rubber chemicals are:

Accelerators. Many different compounds are used to speed, to varying degrees, the vulcanization of rubber. Without accelerators, vulcanization of rubber would be so slow that fabricated products would be far more costly.

Activators and retarders. These chemicals increase or decrease the effects of accelerators. Activators are used far more than are retarders. Most activators are alkaline materials. Conversely, most retarders are acidic. Retarders are used much less often and mainly to minimize premature vulcanization during processing.

Antidegradants. Sometimes called age resisters, this very large class of compounds includes antioxidants, antiozonants, ultraviolet light protectors, and antiflex agents. Most of these compounds are designed to work by inhibiting the reactions between oxygen and elastomers. Carbon blacks and other materials used in compounding rubber also provide protection against degradation. However, because those materials have other primary uses, they are usually classified elsewhere.

Miscellaneous rubber-processing chemicals. This group includes the many processing aids used to reduce the time and energy required to prepare elastomers for the fabricated products. It also includes bonding agents, dispersing agents, colorants, flame retardants, and blowing agents. Peptizers, many of which are organic sulfur compounds, help to break polymer chains, and are the most commercially significant of the group. Other processing aids are various synthetic resins, fatty acids and derivatives, petroleum fractions in the lube oil range of hydrocarbons, and various natural fats, oils, and pine products. A host of bonding agents, many of them proprietary materials, are used to bind the elastomer to metals and textiles that make up the composites that are fabricated rubber products.

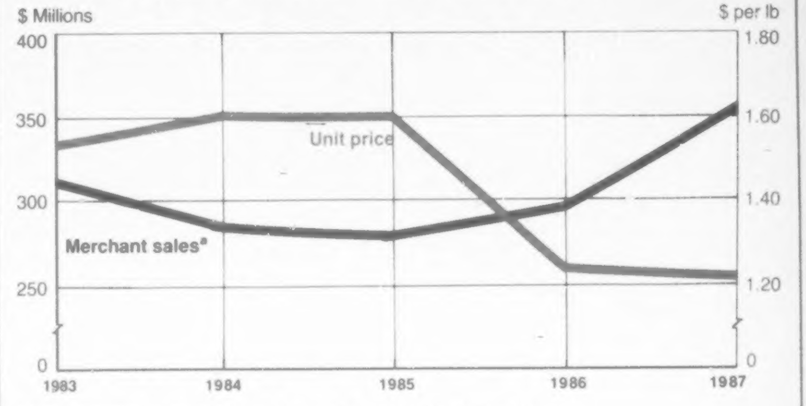
and efficiency improvements in plants that make processing chemicals might provide some capacity increases to meet part of expected added demand. For example, demand for the synthetic rubber produced in largest volume, solid styrene-butadiene rubber (SBR), amounted to 2.38 million metric tons in 1988 in noncommunist countries, according to IISRP estimates. This year use is forecast to rise to 2.41 million metric tons, and to increase 8.8% to reach 2.62 million tons in 1993. Demand for SBR in latex forms is forecast to rise from 1.34 million metric tons this year to 1.45 million tons in 1993.

IISRP forecasts demand for other synthetic rubbers to grow by similar rates. Polybutadiene demand also will increase 8.8% from 1.12 million metric tons in 1989 to 1.22 million tons in 1993. The growth in demand for ethylene-propylene rubbers will be higher, at more than 15%, over the five-year period. Demand for other synthetic rubbers, including butyl and polychloroprene, will climb 123,000 metric tons by 1993, or 12% over the 1.04 million metric tons forecast for this year.

Demand for natural rubber in noncommunist countries will slightly exceed that for synthetic rubber. Between 1989 and 1993, use of natural rubber will rise 9.8%, IISRP forecasts. The area with the fastest growing demand for natural rubber is Asia and Oceania, where total rubber use in 1993 will exceed that of Canada and the U.S.

If demand for fabricated rubber products follows current forecasts, construction of new capacity for rubber-processing chemicals will begin too late to stave off a further tightening of supplies. No large, new units are seriously planned in the U.S., in Western Europe, or in the Far East. Competition during weak periods of demand for rubber-processing chemicals during the early 1980s pushed down prices. By 1986, the average unit price for U.S. merchant sales had declined about 25%, according to ITC. During the latter part of 1987, however, prices for most rubber-processing chemicals began to rise, along with prices of other chemicals. Producers say that, though prices continue to rise, they generally have not returned to levels of a decade ago. Meanwhile, production costs have risen substantially. Therefore, returns remain well below reinvestment levels, especially since costs of plant construction started to rise again about the same

Sales rise, prices hold for rubber-processing chemicals



a Excludes chemicals consumed captively. **Source:** International Trade Commission

time as did selling prices for rubber-processing chemicals.

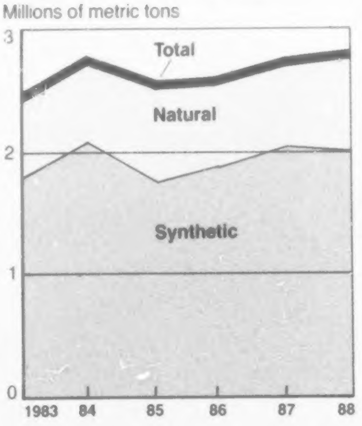
Tight supplies and higher prices for rubber-processing chemicals suggest a shift toward lower use. Fabricators also seek other ways to provide the desired properties in rubber products. Despite research on ways to reduce use of rubber-processing chemicals (begun just after vulcanization was discovered), their use has slowly increased—although growth has been limited by discoveries of new chemicals that give better properties than those obtained with currently used chemicals. Because of cost/performance requirements, rubber-processing chemicals currently are used at levels sufficient to give desired properties without the need of surpluses to cover unexpected conditions.

Because of changes in fabricated product demand, kinds of elastomers used in products, and fabrication technology, some changes are expected in consumption of these chemicals. For example, changes made in elastomers and improvements in compounding will further counteract effects of oxidation and ozone. Thus, lower antidegradant use will be required, according to results of a study by Freedonia Group, a Cleveland consulting firm. According to Freedonia, however, more accelerators and activators will be needed because of efforts to improve rubber-processing and fabrication efficiencies. The firm projects that consumption of processing chemicals on a unit basis will rise to 133 lb per ton of rubber consumed in 1991 and to 140 lb per ton in 1995 from 122 lb per ton estimated to have been consumed in 1986. Coupled with the small rise in unit consumption, higher selling prices will raise the value of U.S. consumption of rubber-processing chemicals at an average annual rate of 5.7% between 1986 and 1991.

Tires and related products account for more than 60% of new rubber consumption in the U.S. annually. A larger share of natural rubber consumption goes into tires compared with the share of synthetic rubber used in tires. For example, IISRP forecasts that this year tires and tire products will account for 53% of U.S. synthetic rubber consumption, excluding carboxylated styrene-butadiene latex and nitrile latex. Tires and tire products consumption of synthetic rubber will rise, but not so fast as consumption by other rubber products, which will result in the decline in share of consumption by tires and tire products.

Production of passenger car, truck, and bus tires in 1988 totaled 211 million units, according to the Rubber Manufacturers Association. Additional quantities of aircraft, tractor and farm implement, and special industrial tires also were produced. The excess of imports of tires over exports added more than 28 million passenger car, truck, and bus tires to the U.S. supply.

U.S. rubber consumption continues to increase



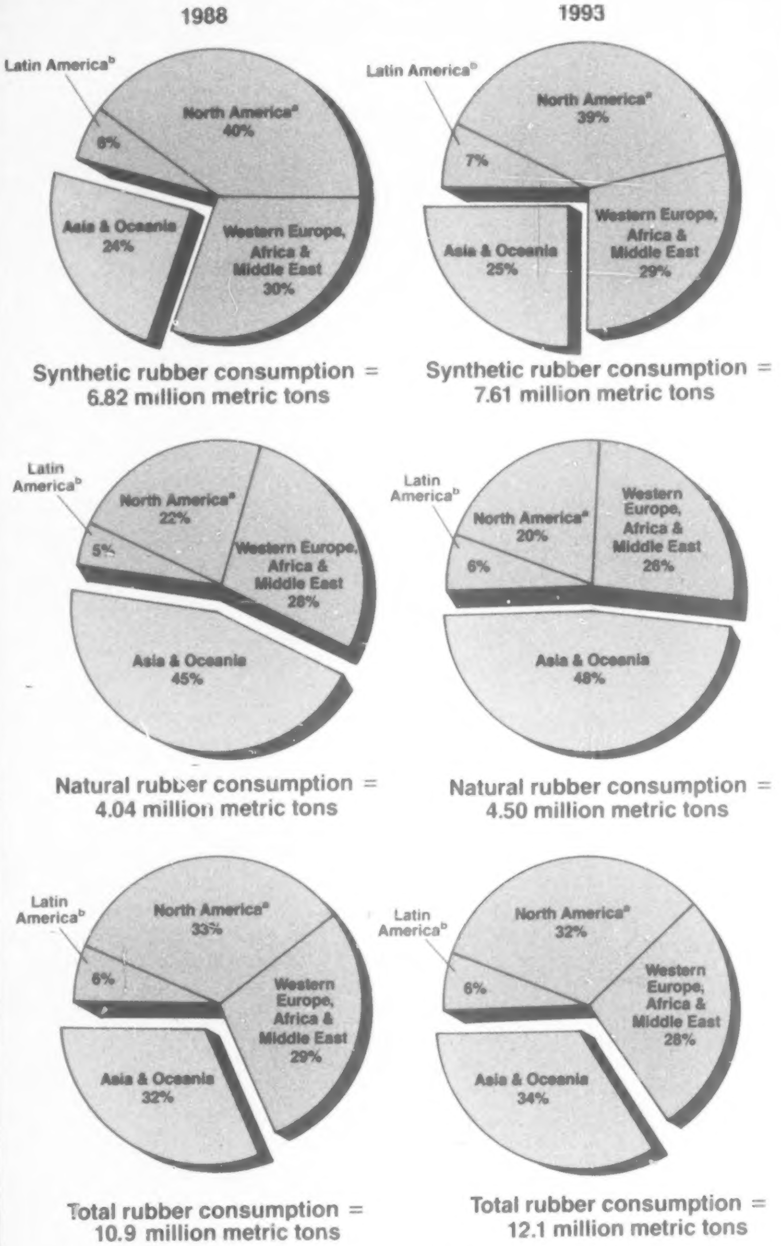
Source: Rubber Manufacturers Association

U.S. passenger car, truck, and bus tire output has held at 200 million units, plus or minus 5% annually for five years. Until some of the capacity expansions that are under way come on stream, tire plants will continue to be utilized at capacity, which tends to hold down production. A large quantity of tire-building capacity was scrapped during the early 1980s when the shift from bias-ply to radial tires for passenger cars neared completion and tire-tread life increases reduced replacement demand. During that time, imports of tires increased rapidly, as did imports of autos, many of which carried tires produced outside the U.S.

Some $2 billion will be spent on tire-building capacity in the U.S. by 1992, if present plans go ahead. In addition, another $4 billion is forecast to be spent for tire capacity in the rest of the noncommunist world. How much these expenditures will increase tire-building capacity is uncertain. A large part of the outlay is going to plants that will build radial truck and bus tires. The conversion from bias-ply truck and bus tires is now well under way. Another part of the expenditures will go to modernizing production facilities in an effort to reduce manufacturing costs.

Changes in tire demand is another uncertainty. For most U.S. cars, and a significant segment of trucks and buses now operating on radial tires, average tire life is growing

Asia and Oceania will become largest rubber-consuming region in Western world by 1993



Synthetic rubber consumption = 6.82 million metric tons

Synthetic rubber consumption = 7.61 million metric tons

Natural rubber consumption = 4.04 million metric tons

Natural rubber consumption = 4.50 million metric tons

Total rubber consumption = 10.9 million metric tons

Total rubber consumption = 12.1 million metric tons

a Canada and U.S. **b** Includes Mexico. **Source:** International Institute of Synthetic Rubber Producers

more slowly than five years ago. A recent shift to higher use of high-performance and off-the-road tires on passenger vehicles offsets the impact of radial tires upon increasing tire life. These high-performance and off-the-road tires, because of their design and use, have shorter tread life than do conventional radial passenger car tires. Although demand will not be noticeably affected by such changes in tire type and use for several years, additional tire-building capacity may be necessary in the 1990s.

Because of the importance of the tire industry as a consumer of rubber, tires will continue to dominate the markets for rubber-processing chemicals. Tire use of chemicals continues to grow, but not so fast as in mechanical goods and other rubber products excluding footwear. Hence, consumption of chemicals in tires is slowly losing share of the market. The tire market, nevertheless, continues to spur developmental efforts by producers of rubber-processing chemicals. Chemicals used in tire fabrication generally are tested for possible use in fabrication of other rubber products, and they are used where possible. Higher value uses in mechanical goods for specific properties will lead to development of a chemical for such uses, but that work is small when compared with chemical development for tire consumption.

Any growth in tire production, therefore, may be expected to drive growth in rubber-processing chemicals. If tire production should increase rapidly as a result of sizable additions in U.S. and foreign capacity, two concerns arise. One pertains to where the additional tires will be sold and suggests a resurgence of competitive pressures. Part of the new capacity will be used for tires going to autos and trucks to be sold in the faster growing markets of developing countries. The remainder of capacity would go to replacing obsolete facilities in the U.S., Western Europe, and Japan, or would be used in competition for market share in existing markets.

The second concern is the availability of capacity for rubber-processing chemicals used in making the tires. Chemical producers, only now seeing recovery in prices after declines in the early 1980s, are expected to be wary of making large investments in plants if selling prices of their products decline under pressure from tire makers who face price competition in tires they sell. Because of the complexity of manufacturing rubber-processing chemicals, sizable new entrants into the market are unlikely.

However, new entrants into rubber-processing-chemicals markets would also be expected to provide the services that producers developed in the 1980s to sell their chemicals in response to competitive pressures. Offering the high degree of technical service and product quality that now is expected of companies to give product differentiation is another barrier to potential new suppliers. Small companies can carve out a niche, but their contribution to the volume needed would do little to increase world supply.

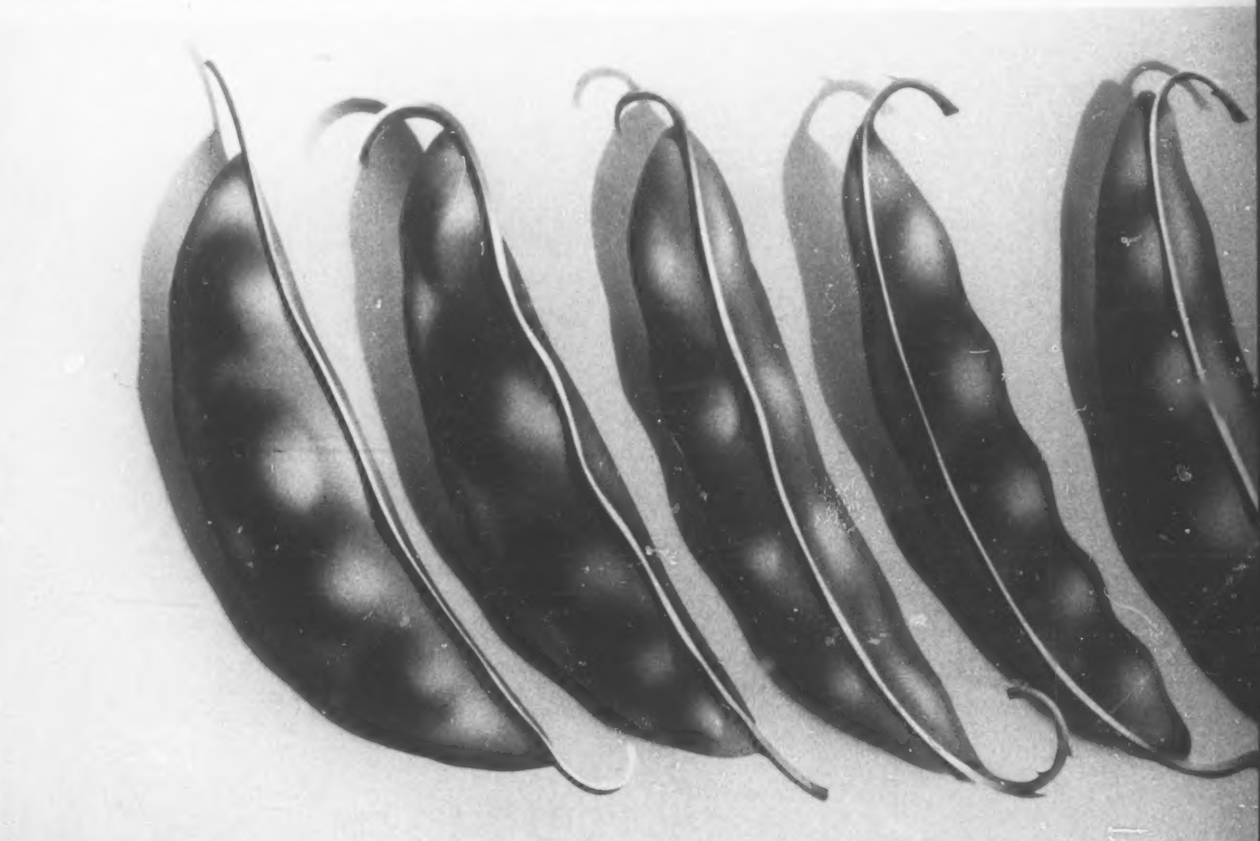
With the changes expected in tire capacity, efficiency of tire building has become more important. Hence, rubber-processing chemicals are needed to improve the efficiency, with much emphasis on the vulcanization process. Except for butyl rubber and some rubbers produced in small quantities, large-volume rubbers can be cured with peroxides. However, most vulcanization still is done by using sulfur or a sulfur-donating chemical. The sulfur vulcanization process causes polymer chains to be connected through sulfur atoms into a three-dimensional form, which provides much greater elasticity and less plasticity. Controlling not only the quantity of materials added to the rubber but also the heat and time influences the properties of the vulcanizate.

Early rubber processers found that use of sulfur and inorganic salts alone took a long time and produced a rubber with poor properties. Minor improvements were made over 50 years, but development of a practical car in about 1900 required pneumatic tires and rubber that was better compounded. Organic chemicals, starting with aniline, were found to speed greatly the vulcanization process and to produce fabricated rubber products with vastly better properties. Toxicity of these chemicals was recognized soon after initial use, and efforts were made to find even better and safer chemicals as vulcanization aids.

The vulcanization aids soon were called accelerators because that was what the first ones did for the vulcanization process. From first use of aniline, a whole business of rubber accelerators, activators for accelerators, and the reverse—retarders—has developed. Products of reactions with aniline aimed at reducing toxicity developed. Some were found also to cause improvement in aging characteristics of rubber. The second major field of rubber-processing chemicals—the antidegradants—then developed.

Numerous organic chemicals—most having one or more sulfur or nitrogen atoms—were tested as vulcanization accelerators prior to the mid-1920s. Among them: dithiocarbamates, xanthates, guanidines, and thiurams. However, nearly all of the compounds in these groups had deficiencies. They frequently were unstable during processing or were overactive and less controllable than processors wished. Some of these accelerators are still used today in limited quantities for specialized types of fabricated rubber products.

The search for better accelerators



has led to 2-mercaptobenzothiazole (MBT) and to development of a whole class of benzothiazole accelerators. Of organic accelerators, activators, and vulcanizing agents reported to ITC, the thiazoles account for more than 90% of production. It is estimated that today more than 100 different compounds, blends, and proprietary mixtures can be obtained commercially for use as accelerators.

The advent of synthetic rubbers and new types of carbon black with finer particle sizes has spurred the search for better accelerators. But compounds of rubber, carbon blacks, and fillers have become more difficult to process. Temperatures during the mixing rise, possibly causing vulcanization or curing to occur sooner than desired. Rubber in which premature vulcanization occurs will have poor properties. Such rubber is called scorched, and is likely discarded or used in a low-value product.

The tendency for MBT accelerators to scorch synthetic rubbers prompted Monsanto to develop a class of compounds, sulfenamides, made by reacting MBT with various kinds of amines. Sulfenamides, also now sold by several rubber-processing chemical suppliers, account for a large share of the chemicals sold as accelerators. They are sometimes called delayed-action accelerators. Cure rates and scorch safety (time before scorch occurs) will vary, depending on selection of the amine used in making the benzothiazolesulfenamide. Highly hindered amines or less basic amines generally will cause slower cure rates.

Some thiazoles, other than the sulfenamide derivatives, are being replaced in rubber fabrication because of growing recognition that decomposition products may include nitrosamines, which are suspected carcinogens. The nitrosamines have been detected in concentrations higher than normal in locations where rubber products are made or stored. They are being brought under toxic substances control legislation that now is either in place or is being considered for enactment in many countries, including the U.S.

The smaller volume commercial accelerators include dithiocarbamates and derivatives such as the thiurams. In the rubber industry, these compounds are considered as ultra-accelerators because they have fast curing abilities. In some vulcanization processes, these compounds will provide enough internal sulfur to produce vulcanizates that contain short cross-links and that have good resistance to heat and oxygen. They also may be used with thiazoles and sulfenamides in proprietary formulations so that the vulcanization rate can be adjusted. These materials most often are used in fabricating hose and other mechanical rubber goods.

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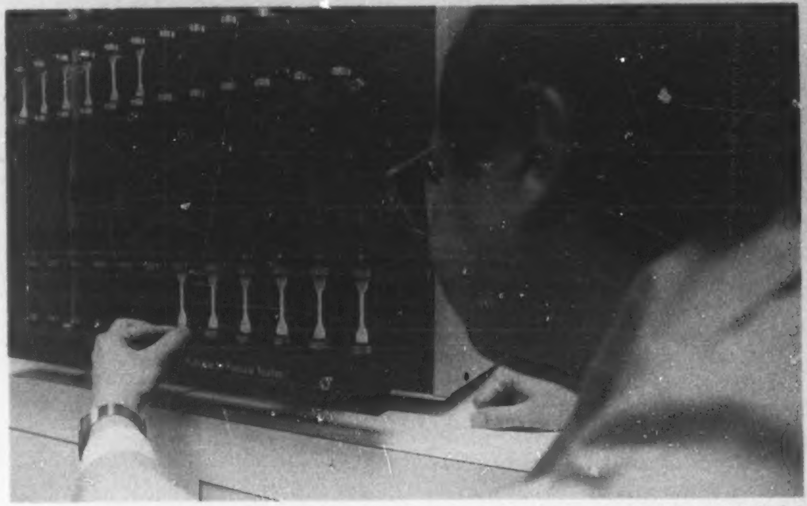

Monsanto technician tests sample of rubber product at company's Akron R&D lab

other materials known as activators frequently are used to increase the effects of accelerators in rubber fabrication. Stearic acid and zinc oxide long have been a combination that rubber processors favor, because the cross-linking is speeded up. Other fatty acids (often mixtures such as are found in vegetable oils) and other metal oxides (such as litharge or magnesia) also are used as activator systems. Despite extensive study, the way that activators work is not yet clearly known.

Neither is the process by which retarders work to slow premature vulcanization fully understood. Retarders are used to extend the time to prepare rubber products for vulcanization (including the various steps from mixing to assembling the final product). Retarders now most widely used in rubber processing are aromatic acids, anhydrides, and phthalimides, or other complex amine derivatives. Choice of retarder will depend on several factors: the kind of elastomer being processed, the accelerator or accelerator system being used, the amount of processing needed, and the temperatures to be used. Use of retarders represents a trade-off between prevention of materials loss (in prematurely vulcanized rubber compounds) and lower productivity because of longer times required during molding.

Long-term performance of the rubber product depends on its retaining good physical properties. Most elastomers are attacked rather rapidly by oxygen, ozone, heat, light, mechanical stress and fatigue, and various chemicals (all of which reduce performance of the product). Chemicals added to rubber compounds to prevent attack on the elastomers generally are called antidegradants, or age resisters. Carbon black and other materials also will significantly help compounded rubber to resist degradation. These materials, however, usually are listed separately from the group of antidegradants. Surface coatings some-

Many chemicals are used to vary vulcanization rate

	Relative rate of vulcanization	Typical compound
Aldehyde/amines	Fast	Butyraldehyde-aniline
Dithiocarbamates	Very fast	Zinc dimethyldithiocarbamate
Guanidines	Slow	1,3-Diphenylguanidine
Sulfenamides	Fast	*N*-cyclohexyl-2-benzothiazolesulfenamide
Thiazoles	Medium	2-Mercaptobenzothiazole
Thioureas	Medium	Ethylene thiourea
Thiuramsulfides	Fast	Tetramethylthiuramdisulfide

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Styrene-butadiene rubber holds share of consumption

Thousands of metric tons	1987	1988	1989[a]	1993[a]
SBR solid	2324	2382	2405	2616
SBR latex	241	245	250	265
Carboxylated latex	984	1049	1088	1189
Polybutadiene	1044	1098	1117	1215
Ethylene-propylene	498	540	557	642
Polychloroprene	249	251	251	258
Nitrile (solid and latex)	221	237	240	262
Other synthetics[b]	958	1022	1040	1163
TOTAL	6519	6824	6948	7610

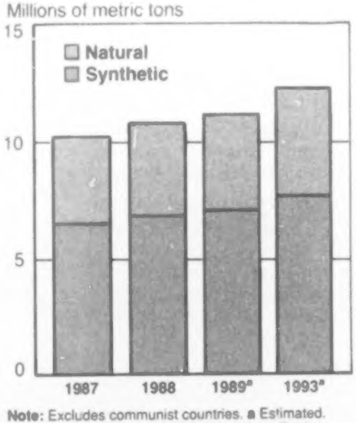
Note: Excludes communist countries. a Estimated. b Includes butyl and polyisoprene. Source: International Institute of Synthetic Rubber Producers

times applied to mechanical goods (to prevent oil or ozone from reaching the elastomer) also are excluded from the antidegradant group.

Results of the oxidation of elastomers appear in either of two ways—hardening or softening of the rubber. Cross-linking during oxidation will occur in rubbers containing butadiene molecules, increasing the rubbers' stiffness and brittleness and decreasing elongation. This will give a leatherlike feel to the surface of the rubber. If the rubber contains an isoprene molecule, softening and weakening will occur, and a stickiness will appear as the elastomer chains break.

Much of the effort toward developing antidegradants is directed at antioxidants. Studies in oxidation of elastomers and the function of antioxidants in reducing the effects of oxygen currently show the possibility that antioxidants moderate the polymer chain degradation by interfering with reactions of oxygen-containing radicals formed from the initial oxidative attack or from chain termination.

Global use of natural and synthetic rubber to rise



Note: Excludes communist countries. a Estimated.
Source: International Institute of Synthetic Rubber Producers

The performance demands that have been put on rubber products for more than 100 years have led to the testing of a wide variety of chemicals as antioxidants, many of which were then discarded. Currently, the most widely used antioxidants fall into the categories of amines, phenols, and thioesters. Diphenyl amines, paraphenyl diamines, and dihydroquinolines are the most used amine antioxidants. Various naphthylamines are nearly no longer used because of concerns over toxicity.

Most commercial antioxidants that contain a phenolic structure fall into five general classes: hindered phenols (with varying side groups on the ring), hindered bisphenols, hindered thiobisphenols (in which sulfur replaces a hydrocarbon group in the bridge structure), polyphenols, and polyhydroxyphenols. Some of the phenolic antioxidants now are used more widely to stabilize synthetic rubbers prior to compounding than they are to provide antioxidant properties to the finished product.

Phosphite antioxidants frequently are used as elastomer polymer stabilizers, and probably more go to this use than to compounding. Many chemical structures of phosphites are available from rubber-processing chemical suppliers, including both alkyl and aryl groups designed for specific applications. These materials often are sold as proprietary mixtures that also may contain other processing chemicals.

Industrial work boots use variety of rubber-processing chemicals

Many of the amino compounds used as antioxidants provide protection against ozone. *p*-Phenylenediamines have been and continue to be the most widely used class of antiozonants in rubber products. Many different derivatives of these diamines are relatively easy to make by reacting various ketones and *p*-phenylenediamine. Proprietary compounds sometimes are sold for specific elastomers or for use in producing certain kinds of fabricated rubber products. Other lesser used antiozonants include such groups of compounds as dihydroquinolines, thioureas, and dithiocarbamates.

For protection against attack by ozone, paraffin wax likely is used in greater quantities than synthetic chemical antiozonants. Wax usually is blended into the rubber compound and dissolves into it during mixing if temperatures are high enough. Otherwise, it will dissolve later during the heating to produce vulcanization. Because wax has limited solubility, it will "precipitate" when the rubber product cools and will migrate to the surface of the product. At the surface, it provides a layer of material attacked very slowly by ozone. If the wax on the surface is removed by abrasion or dynamic stress, the rubber will be attacked by ozone until more wax migrates to the surface of the rubber product. Because scuffing or flexing tends to remove waxes, chemical antiozonants also are used in most rubber products where any movement at all is anticipated.

Selecting the wax to be used has become as complex a matter as selection of the other chemicals used in rubber processing. There are wide variations in the kinds of waxes available to rubber compounders. Low-melting-point waxes (extracted from cuts of crude oil with boiling points in the range of lubricating oil stocks) largely are straight-chain paraffins with low molecular weights. Rubber compounders include some of the high-molecular-weight and branched-chain paraffins (such as microcrystalline waxes) to give long-term protection against ozone.

The diffusion rate of waxes added to rubber compounds for ozone protection is affected by other components of the compound (such as type and quantities of fillers) and by temperature. At low temperatures, the low-molecular-weight waxes will migrate to the surface of the rubber product fast enough to give protection. At higher temperatures, the low-molecular-weight waxes remain soluble in the rubber and don't migrate. To get ozone resistance, high-molecular-weight waxes must be included in the wax package that is added to the rubber compound.

Adding a relatively large quantity of an ozone-resistant rubber [such as terpolymers of ethylene, propylene, and diene monomers (EPDM)] to the compound is another way to protect elastomers such as styrene-butadiene rubber and natural rubber. Although this technique will work well for some products, it may change the properties of the final product in ways unacceptable for marketing in others. One exam-

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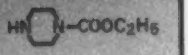
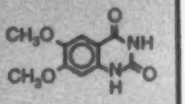
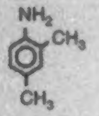


1-Ethoxycarbonylpiperazine



6,7-Dimethoxy-quinazoline-2,4-dione



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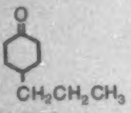
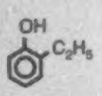


4-Propylcyclohexanone



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ple of attempting to use EPDM in this way is in tires, which can be severely attacked by ozone in the sidewalls if antiozonants are not added to the sidewall compound. So far, EPDM in sidewalls (other than in the decorative white stripe) hasn't given the flexing properties that are desired for long tire life.

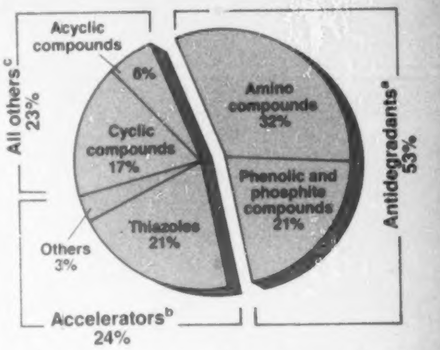
Combining well the different types of elastomers, accelerators, activators, antidegradants, the several fillers and reinforcers, and other materials useful for fabricating a rubber product requires efficient mastication. Such mastication of rubber is necessary to make it later form smoothly. Elastomers, whether produced from tree latex or synthetically, generally are tough. They need materials that will reduce the very high viscosity to allow easier mixing of all the other components that make up a rubber compound for use in fabricated products. These materials also will lower processing temperatures that otherwise could cause scorching, and they will reduce the energy consumption required for mixing.

A large number of different materials—called peptizers as a group—have been and are being used in mechanical processing. New peptizers come to market frequently with better properties than those of currently used peptizers. As a result, numerous changes are made in the materials used in fabrication plants. Peptizers act on elastomers to reduce molecular weights of the polymers by chain cleavage and viscosity of the polymers. Use of peptizers rarely will affect vulcanization or final properties of the rubber product.

Many of the peptizers are complex aromatic disulfides and mercaptans that work by initiating radical sites that cleave polymer chains. They also neutralize previously formed radicals and promote oxidation. Natural rubber peptization is done most easily, and peptization of nitrile rubber is the most difficult among the major volume elastomers.

Semipeptizers is a name given to a group of sulfonated compounds and mineral oils used to break down elastomers. These materials appear to work mechanically to break polymer chains during mastication. Because costs are lower than for more complex chemical peptizers, these materials are used in larger quantities, relative to the amount of elastomer used. In addition to providing a milder form of peptization, these materials also have worthwhile mold release properties.

Antidegradants make up more than half of rubber chemicals



Total 1987 production^c = 382 million lb

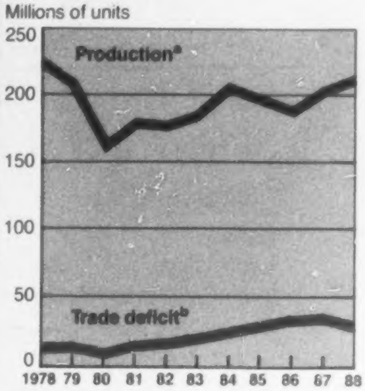
a Antioxidants, antiozonants, stabilizers. b Includes activators and organic vulcanizing agents. c Excludes carbon black, sulfur, and fillers. Source: International Trade Commission

Besides the peptizers, a wide variety of materials are used as dispersing and processing agents to help the mastication process. Most of these materials differ from peptizers in that they do not react chemically with the polymer chains to break them. Examples of these agents are numerous; they include low-molecular-weight resins, fatty acids and their esters, and metal soaps. The resins are made to contain components that are compatible with elastomer aliphatic, aromatic, and naphthenic groups to improve homogeneity.

Fatty acids and their derivatives act as lubricants between polymer chains, causing easier flow during shearing when elastomers are being masticated. Most of these materials have only limited solubility in rubber compounds. They also reduce sticking of rubber compounds to processing equipment.

A host of other materials are used as softeners, plasticizers, and extenders of rubbers. Distinction between these materials and the dispersing and processing agents often is blurred because they do the same

U.S. tire production slowed by imports



a Passenger car, truck, and bus tires only. b Excess of imports over exports. **Sources:** Rubber Manufacturers Association, Department of Commerce

job. The exact material to be used will depend on the kind of elastomer going into the fabricated rubber product and on the properties wanted in that product.

Today a very large share of synthetic rubber that leaves the polymerization plant contains oil, especially the rubber destined to be made into tires and mechanical goods where color of the finished rubber product is black or doesn't matter. The combination of oils, carbon black, and polymer is called masterbatch. The oil undoubtedly has a softening effect on the elastomer. Later during processing, additional and different kinds of petroleum oils may be added to the compound. Many specifications are given for oils used in rubber processing, ranging from types of hydrocarbons present to viscosity. For example, oils with a higher content of aromatic hydrocarbons allow faster mixing of components of a rubber compound and faster cure rates during vulcanization. Aromatic oils, however, reduce both resiliency and good aging characteristics when compared with oils higher in paraffins.

Other materials used in lesser quantities in rubber processing as softeners and plasticizers are turpentine (useful because it contains significant quantities of terpenes that are oligomers of isoprene, a basic structure of natural and polyisoprene synthetic rubbers), pine tar, terpene resins, some synthetic resins (such as coumarone-indene and petroleum hydrocarbon resins), various esters, and natural fats and oils (other than those from pine trees). Small supply and high cost limit the use of many of these materials. Most will be used in low-production-volume products because they give specific advantages in cost/performance considerations. Properties of these materials cover a wide range and may be adversely affected by other components in a rubber compound.

Other materials are used in rubber compounding to provide certain properties in fabricated rubber products. The quantities of these materials used in rubber vary widely but, as a group, are much smaller than the accelerators and antidegradants. This miscellaneous group of rubber compound components includes bonding agents, flame retardants, colorants, and blowing agents.

For many fabricated rubber products, bonding agents are used to bind the elastomer to a reinforcing material for the products. The reinforcing materials are mostly metals and synthetic and glass fibers. A wide range of materials are used as bonding agents, depending on the composition of reinforcing material, form, and anticipated service.

Most steel wire used in reinforcing tires is first electroplated with brass. When the rubber compound contacts the brass as the tire is assembled, two competing chemical reactions occur at the interface of wire and rubber. In one reaction—a part of vulcanization—sulfur reacts with the elastomer. In the other, sulfur reacts with the copper in the brass. Good adhesion and long-term performance depend on high quality and uniform plating and upon avoidance of contaminants including water and nitrogen. Cobalt salts sometimes are used to improve the metal-elastomer adhesion.

Other methods of bonding elastomers to metals and textiles involve many different chemicals. Dipping the fiber in a mixture of resorcinol, formaldehyde, and latex (RFL) is basic to the bonding. Silanes may be used with glass fiber. Resorcinol and certain amines (such as hexamethyl tetramine as a methylene group do-

Adhesives from Renewable Resources
385

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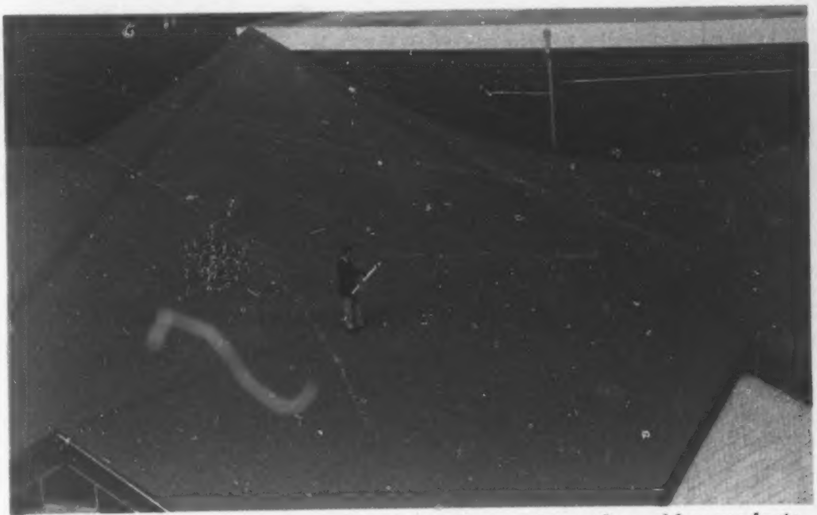
nor to polymerize the resorcinol) are added as bonding agents to the rubber compound, which is contacted with RFL-dipped reinforcements. Various complex isocyanates in organic solvents also may be applied by various physical methods to fibers, textiles, and metal parts, to bond them to elastomers.

Flame retardants are relatively high-cost chemicals added to rubber compounds when resistance to burning is considered to be a necessity. Examples are products such as carpet backing, underground conveyer belts, and single-ply roofing. Fillers, such as clays, aid flame retardancy. Frequently, antimony oxide and chlorinated paraffins or brominated aromatics are combined so that, if burning occurs, reaction products of antimony trihalides and steam dilute the oxygen around the burning part. Other flame retardants used less often are aluminum and magnesium hydroxides and ammonium phosphate. There are problems in using flame retardants in suitably high concentrations in that they may alter properties of the rubber product unacceptably.


Goodyear photo

Flame retardants are used in single-ply roofing, various other rubber products

Colorants are used in rubber compounds for a number of consumer products such as gloves, toys, bathing caps, and bottles. Cost, effect on properties, insolubility in the rubber compound, and compoundability are among factors that rubber processors consider in selecting colorants. For whites, titanium dioxide predominates. This chemical also is used with organic pigments to obtain pastel colors. Use of colorants often will require a change in the kind of other processing chemicals put into the compound to avoid staining or other deterrents to good coloring.

Blowing agents are used to produce the small quantities of foam or sponge rubber required in limited markets. Because most sponge rubber applicationss need closed-cell foams, blowing agents are selected to evolve gases, mostly nitrogen, by thermal decomposition. Among the commercially important blowing agents are complex azides, diazoaminobenzene, and some amines.

Still other chemicals are used for special purposes in compounding and fabricating rubber products, all developments of the long history of the consumption of elastomers in useful products. Further development of rubber-processing chemicals will be spurred by changing market needs. When demand becomes strong enough to render making rubber products for a market profitable, then production begins, bringing demand for processing chemicals along with it. □

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Scientific news from the Dallas ACS meeting

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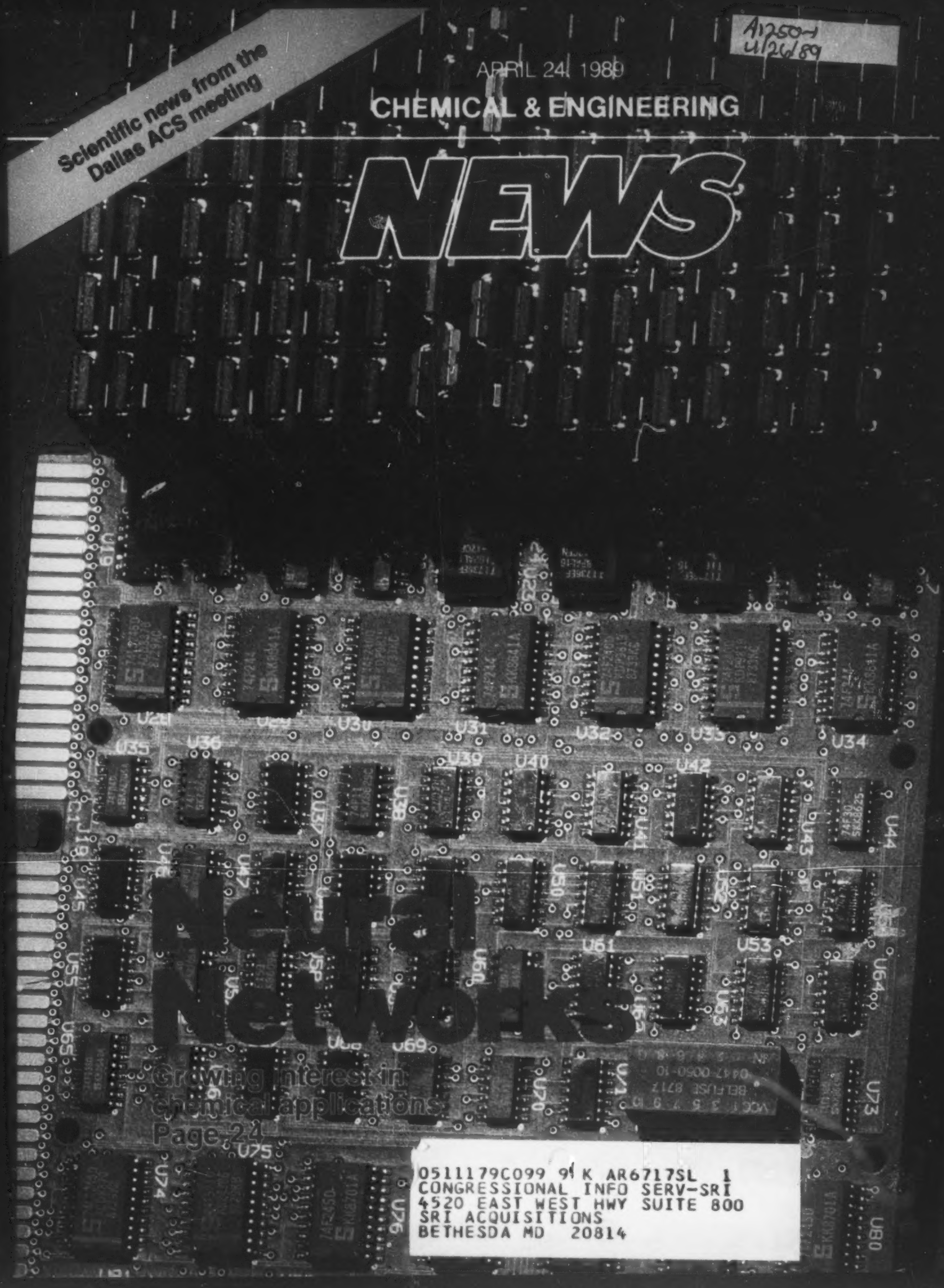
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Neural Networks

Growing interest in chemical applications
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NEWS

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APRIL 24, 1989

News of the Week

- **New data are emerging from researchers at University of Utah, other labs, but skepticism persists over Utah claim of a sustained fusion reaction in simple electrochemical cell.** **Page 4**
- **D. Allan Bromley, a Yale physics professor, apparently has been chosen as White House science adviser.** **Page 5**
- **Delegates from U.S., 35 other nations meet in Helsinki to explore faster phaseout of CFCs.** **Page 5**
- **Planned merger of agricultural businesses of Dow Chemical and Eli Lilly will create one of world's biggest agricultural product companies.** **Page 6**

Cover: Floating point processor for IBM PC/ATs is used to create large-scale neural network simulations. Photo courtesy of Science Applications International Corp.

Letters 2

Concentrates
Business 13
Government 18
Science/Technology 23

The Departments
Meeting Briefs 42
Meetings 46
Newscripts 64

News Focus

Kyle Olson of the Chemical Manufacturers Association discusses the complexities inherent in verifying a chemical arms treaty. **Page 7**

Business

U.S. consortium signs trade agreement with Soviet group, opening way to joint ventures; West European venture helps restore order to PVC market; now publicly traded, Arco Chemical reports strong sales, earnings in 1988. **Page 15**

Government

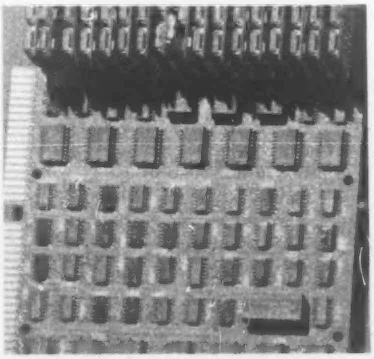
White House, Congressional agreement on framework for fiscal 1990 budget decisions spells good news for science; Department of Health & Human Services creates two new offices to deal with science misconduct issues. **Page 19**

Science/Technology

From ACS meeting in Dallas: Plenary session addresses biotechnology and environment; field tests of recombinant organisms can be carried out safely; improved polymeric adsorbents for HPLC developed; vapor deposition is key to new lubrication method; many foods contain anticancer substances; more effort needed in coal combustion research; first direct observation of friction at atomic level made; NMR finds new uses in surface science, catalysis studies; flexible plastic robot fingers have electrically activated grasp; advances made in biotechnology route to tenacious adhesives; improvements made in processes for formaldehyde and for acetal copolymer. **Page 28**

ACS News

Photos from Dallas indicate variety of activities held during society's national meeting. **Page 44**



Cover Story

Interest in the use of neurocomputer systems in chemical applications is growing, as systems show promise for predicting chemical reaction products, drug side effects, protein folding. **Page 24**

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LETTERS

Fraud in research

SIR: The question of fraud and carelessness in research (particularly biomedical research) is getting continued publicity and is attracting the attention of not just the granting agencies like the National Institutes of Health, but even of Congressional committees. Exaggerated or not, there is a growing concern among the public that all is not well, and the probity of the scientific enterprise is coming increasingly into question. Clearly universities are going to be asked to institute formal policies to deal with such matters, and I feel serious apprehension about the complications this will entail. In the meantime, working scientists must recognize the problem and take steps to decrease the frequency of such betrayals of our scientific ethics. I feel strongly that, at least in my own field of chemistry, two major keys to meeting the problem are simply the keeping of good records, and the proper assumption of responsibility by senior investigators. These are matters on the importance of which we all agree, but their implementation is easily eroded by carelessness, impatience, and the rush to get out results. In fact, I will make no claim to have always been blameless myself.

Deliberate fraud by senior investigators is rare, and in academic chemistry I cannot recall a clear-cut case during the 50 years I've been in the business. Fabrication of data by students (or other junior members of a research group) is, unfortunately, not as uncommon and occurs most frequently to meet a deadline, to complete a thesis or publication, or to force recalcitrant experiments to fit some preconceived pattern. This side of deliberate fraud, there is, as we all know, a large morass, which I may call subjective treatment of data. Into this we all step, and, occasionally, some of us become badly mired. Basically, it involves selecting and arranging data to support a favored hypothesis. Much of this is legitimate, and indeed necessary if a comprehensible publication is to be distilled from a mass of data accumulated over a long period. On the other hand, as we grow increasingly enamored with our hypotheses, such selection can easily get out of hand. Since confidence in our own ideas and the ability to present our results in the most favorable light increase with experience, it is here that senior investigators most often go astray. We all have to walk a delicate line, and occasionally step over it. Such overly subjective interpretations of data are probably a major source of the polemics that occasionally burst forth and enliven our science. Some are significant, but many rather trivial.

The canons of science demand that experiments be clearly described and their results honestly reported. That this is being done can be validated only if complete and accurate records are maintained. That this is being done within his (or her) group is clearly one of the serious responsibilities of a senior investigator. Students and junior colleagues need to be instructed on how, and in how much detail, records should be kept, and a responsible investigator needs to periodically check that records are satisfactory and are being properly preserved.

Although there is (or at least used to be) some instruction in the matter in undergraduate courses, the practice of good record keeping does not necessarily come naturally to students. That they learn and become accustomed to it is, however, most important in the training of young scientists if they are going to develop into mature and independent investigators. Industry certainly gives it great weight, and insists on detailed records of all research, both for patent purposes and legal protection.

Although most students and junior investigators intend to be honest, good and meticulous records are also a strong disincentive to fudging data, overlooking inconvenient results, and giving undue weight to sloppy or incomplete work. This makes them an important barrier to both fraud and the undue massaging of data in the first place, not to mention that good records are vital in identifying the source of trouble if results cannot be reproduced or published work comes under criticism.

Responsibility and good records become particularly important when cru-

Corrections

- March 27, page 7: Levels of sulfur dioxide and nitrogen dioxide should have been expressed as µg per cubic meter, not µg per square meter.
- April 10, page 25: The starting compound depicted in the diagram should have been $(C_6H_5)_2C{=}N{-}CH_2CO_2tBu$, not $(C_6H_5)_2{=}N{-}CH_2CO_2tBu$.

A1250-1
5/4/89

More scientific news
from Dallas meeting

MAY 1, 1989

CHEMICAL & ENGINEERING NEWS

Top 100
Chemical Producers

Page 11

CHEMICAL & ENGINEERING
NEWS

Volume 67, Number 18
CENEAR 67 (18) 1–84
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MAY 1, 1989

News of the Week

- **While skepticism may be growing among scientists over claims of cold fusion, Congress is anxious to know what the federal government can do to speed progress in the area. Page 6**
- **Bigeye binary chemical bomb is panned by panel of experts formed by Comptroller General at the request of the Pentagon. Page 7**
- **How to proceed on mapping the human genome is an open question, despite broad agreement that the project should proceed. Page 7**
- **U.S. delegates in Helsinki this week at international meeting on protecting the ozone layer are pushing to add carbon tetrachloride and methyl chloroform to list of compounds regulated under the Montreal protocol. Page 8**
- **Hoffmann-La Roche restructures its complex share-ownership structure to make shares more tradeable and bring the firm in line with new Swiss legislation. Page 9**
- **National Academy of Sciences elects 60 new members, a number of them chemists. Page 9**

Letters 4
Editor's Page 5

Concentrates

Business 17
Government 21
Science/Technology 26

The Departments

New Products 46
Books 57
People 65
Meetings 66
Newscripts 84

Business

Mobay introduces new nylon engineering resins, Monsanto and Toray Industries form joint venture, as producers of these resins gear up to meet growing market; Koch Industries will provide $30 million of equity funding for joint technology venture with Catalytica. **Page 19**

Government

Budget matters, environmental issues have occupied much of the 101st Congress' attention in its first three months; as the effect of Alaska's huge oil spill continues to expand, public doubts are growing over the handling of the accident by Exxon and government agencies. **Page 22**

Science/Technology

Efforts to improve researcher access to biotechnology information sources increase; modifying electrodes using organized monomolecular assemblies allows for higher selectivity; new computational chemistry systems extend current capability in a number of areas. **Page 27**

Education

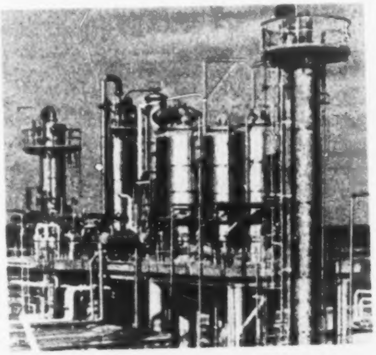
Committee on Professional Training reviews new biochemistry, education, and polymer options for undergraduate chemistry programs. **Page 49**

Priestley Medal Address

George Pimentel calls for chemists to take an active role in a campaign of public education on the benefits and risks of chemicals. **Page 53**

ACS News

Council voted for no increase in membership dues for next year at the national meeting in Dallas last month. **Page 62**



Top 100

Combined sales of the 100 largest U.S. chemical producers in 1988 were up nearly 18% from the previous year to a record $171 billion, reflecting the industry's continuing good health. Page 11

Chemical & Engineering News

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LETTERS

Neutral hydrolysis of peptide

SIR: I would like to draw attention to an important application of the hydrolysis rate of a peptide, PhePhePheGly, measured by D. Kahne and W. C. Still [*J. Am. Chem. Soc.*, **110**, 7529 (1988), and C&EN, Nov. 7, 1988, page 17]. The first-order rate constant at neutral pH and 25 °C is $k_h = 3 \times 10^{-9}\ s^{-1}$, which translates into a second-order rate constant of k_{HOH} 10^{-10} $M^{-1}\ s^{-1}$ for the uncatalyzed hydrolysis of peptides. This data can serve as a reference point not only for the efficiency of enzyme mimics but also for the efficiency of the enzymes that catalyze the decomposition of peptides (any other point of reference may be just as arguable).

Although serine protease-catalyzed reactions may have some different features, evolved precisely to accomplish the observed efficiency, from the nonenzymatic hydrolysis of their substrates, the rate acceleration with respect to the uncatalyzed hydrolytic reaction would include all components of catalysis enzymes evolved to employ. If serine proteases do or ever will catalyze the hydrolysis of their natural peptide substrates at the rate of diffusion (k_b 10^9 $M^{-1} s^{-1}$), at the "speed limit," these then involve rate accelerations of 10^{19}—a surprising feat.

Actually, there must be some serine proteases, likely to be thrombin, that react with their natural substrates at nearly the diffusional rate. One may infer this from our recent use of chromogenic anilide substrates (Hemker, H. C., editor, "Handbook of Synthetic Substrates," page 70, Martinus Nijhoff Publisher, 1983) that are quite inert themselves (k_{HOH} is very likely to be $<10^{-9}$ $M^{-1}\ s^{-1}$), but some of which hydrolyze at rates k_c/K_m 10^6 to $10^8\ M^{-1} s^{-1}$ with the serine protease they select for. Efficient catalysis of extended peptide substrates by serine proteases is associated with K_m values 10^{-7} to 10^{-5} M and $K_c < 300\ s^{-1}$.

In the case of inert compounds, leaving group departure often poses the greatest difficulty to overcome and may have to be the first chemical step for an enzyme to optimize. It certainly is not the rate-limiting step for acetylcholinesterase (another group of serine hydrolase enzymes) catalyzed hydrolysis of acetylcholine [Kovach, I. M., *J. Enzyme Inhibib.*, **2**, 198 (1988)] and may not be for serine protease hydrolysis of natural substrates either. Acetylcholinesterase seems to have gone beyond this point by optimizing all chemical steps in its reaction with its natural substrate, which may not yet be the case with serine proteases.

Notably, artificial enzyme mimic research is focused mostly on acceleration of the initial steps of enzymatic catalysis. Without the efficient removal of a leaving group, however, a correct assessment of the efficiency of the first steps is not possible. It is tempting to speculate that nature had to provide efficient catalysis for leaving-group departure early in the evolutionary process before optimizing other chemical steps.

Ildiko M. Kovach
Codirector, Biochemical Research Services Laboratory
Smissman Research Laboratories
Lawrence, Kan.

Nuclear power

SIR: I certainly agree with Claude Hudgens (C&EN, March 6, page 2) that nuclear energy is a viable and needed energy source. However, he unfortunately resorts to the same descriptive excesses regarding coal that he quite correctly decries about nuclear. Statements such as "strip mining damage is forever" and "coal is a dangerously polluting energy source" are just as inflammatory and untrue as "waste will remain dangerously radioactive for N-thousand years" and

Continued on page 82

1988 ACS Annual Report

In the 1988 ACS Annual Report, which accompanied the April 17 issue of C&EN, the names of two directors-at-large—Joe A. Adamcik and Stanley Kirschner—were inadvertently omitted. Kirschner was elected by mail ballot last April to serve the remainder of the 1987–89 term vacated by Adamcik, who resigned effective May 1, 1988. The editors of the Annual Report regret the error and any resulting confusion. Also, the number of documents cited by Chemical Abstracts Service in 1988 was 578,128, not 474,545.

Top 100 Chemical Producers Post Record Sales

Combined sales of 100 largest firms totaled $171 billion in 1988, up almost 18% from previous year; sales declined for only five of the 100

William J. Storck,
C&EN Northeast News Bureau

Another healthy year for the chemical industry in 1988 is reflected in C&EN's annual compilation of financial results for the 100 largest chemical producers in the U.S. The year created, by far, the biggest Top 100 chemical producers in terms of sales. However, as in the past, continuing restructuring in the industry has brought about change in the companies listed and in the rankings among the companies from the previous year's rank. And, over the past few years, this restructuring has caused major changes in the types of companies producing chemicals.

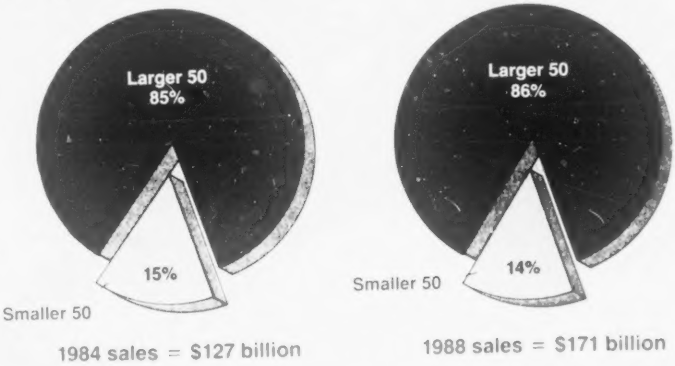
The biggest change for the Top 100 is in the sales that the companies posted in 1988. Total sales for the 100 producers amounted to $171 billion, up almost 18% from that of the 100 companies listed in 1987. And the 1988 sales figure was up about 20% from what the companies listed in 1988 achieved in 1987. Sales growth for the firms listed in 1988 averaged 21% for the 50 larger companies, but just 14% for 48 of the smaller 50 companies for which comparable figures are available.

Sales declined for only five of the 100 companies, the fewest in recent memory, and for one of these, International Minerals & Chemical, the decline occurred because IMC spun off its fertilizer operations into IMC Fertilizer. For two of the companies—Borden Chemicals & Plastics and Sherex, 1987 sales figures were unavailable; therefore, growth could not be measured. Thus, 93 of the companies posted increases in sales in 1988 over 1987.

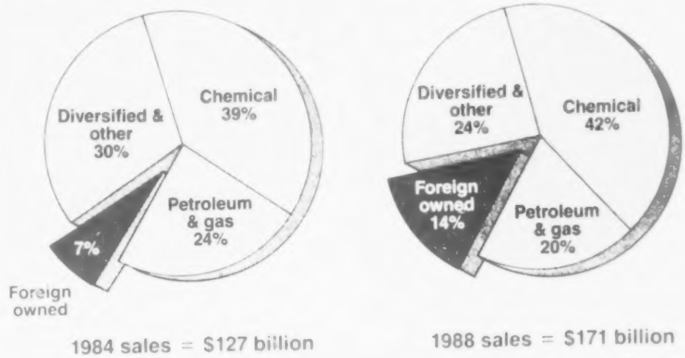
The ranking of the Top 100 producers is based on chemical sales information from annual reports and, in the case of companies not issuing annual reports, other published data or interviews with the firms.

For the third year in a row, the top five chemical producers—Du Pont, Dow Chemical, Exxon, Union Carbide, and Monsanto—held their ranking, with Du Pont the top chemical producer. Although technically classified as a diversified company because of its large sales volume in oil and other areas, Du Pont's an-

Chemical sales split between large and small firms has changed little since 1984...



...but foreign-owned companies have doubled their share of chemical sales



Note: [illegible] with those listed in C&EN, May 6, 1985, page 11

Chemical sales, operating profits increased dramatically for most producers

Rank 1988	Rank 1987		Chemical sales 1988 ($ millions)	Change from 1987	Chemical sales as % of total sales	Industry classification	Chemical operating profits[a] ($ millions)	Change from 1987	Chemical operating profits as % of total	Operating profit margin[b]	Identifiable chemical assets ($ millions)	Chemical assets as % of total assets	Operating return on chemical assets[c]
1	1	**Du Pont**	$14,717	12.8%	44.7%	Diversified	$2612	12.9%	61.3%	17.7%	$10,290	38.3%	25.4%
2	2	**Dow Chemical**	12,128	11.8	72.7	Basic chemicals	3655	89.4	88.0	30.1	10,792	66.5	33.9
3	3	**Exxon**	9,990	39.2	11.4	Petroleum	1863	71.4	21.2	18.6	6,731	9.1	27.7
4	4	**Union Carbide**	7,601[d]	23.1	91.3	Basic chemicals	1542	76.8	96.0	20.3	6,897	88.3	22.4
5	5	**Monsanto**	5,535	7.2	66.7	Basic chemicals	910	18.8	95.3	16.4	4,144	49.0	22.0
6	6	**Hoechst Celanese**	5,369	25.3	94.5	Basic chemicals	563	26.8	102.4	10.5	na	na	na
7	10	**Occidental Petroleum**	4,673	56.2	23.4	Petroleum	1050	163.8	191.6	22.5	5,258	25.3	20.0
8	7	**BASF**	4,536	18.9	88.0	Basic chemicals	na	na	na	na	na	na	na
9	9	**Amoco**	4,352	24.6	18.2	Petroleum	1022	45.2	28.1	23.5	2,920	9.9	35.0
10	11	**Mobil**	4,280	46.3	7.9	Petroleum	851	96.5	19.4	19.9	2,802	7.7	30.4
11	8	**Shell Oil**	4,006	12.0	19.0	Petroleum	746	24.3	34.1	18.6	3,822	14.1	19.5
12	14	**General Electric**	3,539[d]	28.6	7.1	Diversified	733	44.6	12.3	20.7	7,130	6.4	10.3
13	16	**Chevron**	3,204	23.6	11.6	Petroleum	616	55.2	19.0	19.2	2,101	6.7	29.3
14	13	**W. R. Grace**	3,131	12.1	54.1	Specialty chemicals	388	8.7	65.2	12.4	2,204	48.4	17.6
15	15	**Eastman Kodak**	3,033	16.7	17.8	Photo equipment	628	61.9	21.4	20.7	2,875	12.5	21.8
16	12	**Allied-Signal**	3,033	8.5	25.5	Diversified	377	23.2	53.6	12.4	1,839	18.4	20.5
17	19	**Arco Chemical**	2,700	38.3	100.0	Basic chemicals	722	81.4	100.0	26.7	2,548	100.0	28.3
18	17	**Rohm & Haas**	2,535	15.1	100.0	Basic chemicals	377	16.7	100.0	14.9	1,857	100.0	20.3
19	21	**Phillips Petroleum**	2,518	30.6	22.3	Petroleum	911	89.0	46.3	36.2	1,349	11.3	67.5
20	22	**Air Products[e]**	2,237	16.6	92.0	Basic chemicals	409	9.8	108.7	18.3	2,462	87.1	16.6
21	23	**Quantum Chemical**	2,219	18.3	76.0	Basic chemicals	711	104.7	93.6	32.1	1,465	50.4	48.6
22	18	**American Cyanamid**	2,167	10.5	47.2	Basic chemicals	214	11.0	38.9	9.9	1,519	49.4	14.1
23	20	**Bayer USA**	2,140	9.7	45.4	Diversified chemicals	118[f]	40.5	94.9	5.5	na	na	na
24	28	**Ashland Oil[e]**	2,090	27.2	25.5	Petroleum	102	13.3	24.7	4.9	754	17.7	13.5
25	25	**B. F. Goodrich**	2,074	19.1	85.8	Basic chemicals	308	46.5	88.5	14.8	1,358	79.9	22.7
26	32	**Atlantic Richfield**	1,903	36.0	10.4	Petroleum	na	na	na	na	na	na	na
27	26	**Hercules**	1,750	3.6	62.5	Basic chemicals	141	5.2	91.0	8.1	1,376	62.2	10.2
28	29	**Texaco**	1,711	7.8	5.1	Petroleum	379	193.8	11.8	22.2	1,029	3.9	36.8
28	—	**Himont**	1,711	46.8	100.0	Basic chemicals	526	69.1	100.0	30.7	1,044	100.0	50.3
30	31	**Ethyl**	1,674	19.1	61.6	Basic chemicals	309	20.1	70.4	18.5	1,141	22.7	27.1
31	43	**BP America**	1,507	59.8	9.8	Petroleum	na	na	na	na	na	na	na
32	33	**Dow Corning**	1,477	13.3	100.0	Specialty chemicals	151[f]	11.5	100.0	10.2	na	na	na
33	30	**FMC**	1,435	−3.6	43.7	Machinery	224	−7.7	58.4	15.6	1,234	54.1	18.1
34	37	**National Starch**	1,415	17.1	100.0	Specialty chemicals	200	14.1	100.0	14.1	1,110	100.0	18.0
35	34	**Rhône-Poulenc**	1,400	7.7	100.0	Specialty chemicals	na	na	na	na	na	na	na
36	35	**Olin**	1,366	10.9	59.2	Basic chemicals	105	6.1	58.3	7.7	953	49.1	11.0
37	40	**Akzo**	1,347	35.8	100.0	Basic chemicals	76	78.8	100.0	5.6	na	na	na
38	41	**Aluminum Co. of America**	1,215[d]	23.7	12.4	Nonferrous metals	419	569.2	24.1	34.5	2,577	24.5	16.3
39	38	**Unocal**	1,204	12.4	11.9	Petroleum	182	574.1	39.9	15.1	622	6.5	29.3
40	39	**Huntsman Chemical**	1,200	17.4	100.0	Basic chemicals	na	na	na	na	na	na	na
41	46	**Freeport-McMoRan**	1,130	31.5	58.1	Agrochemicals	198	85.9	39.3	17.5	894	24.0	22.1
42	42	**PPG Industries**	1,113	16.8	19.8	Glass Products	255	82.1	27.6	22.9	1,048	20.3	24.3
43	28	**Ciba-Geigy**	1,098[g]	15.7	32.5	Specialty chemicals	na	na	na	na	na	na	na
44	—	**IMC Fertilizer[h]**	1,086	23.9	100.0	Agrochemicals	219	364.1	100.0	20.1	1,472	100.0	14.8
45	45	**Aristech**	1,065	15.9	100.0	Basic chemicals	196	63.2	100.0	18.4	676	100.0	29.0
46	58	**Georgia Gulf**	1,061	49.9	100.0	Basic chemicals	312	92.0	100.0	29.4	457	100.0	68.3
47	44	**Lubrizol**	1,036	10.2	92.0	Specialty chemicals	306	119.5	91.6	29.6	730	75.3	41.9
48	48	**Pennwalt**	1,024	21.0	100.0	Basic chemicals	135	31.5	100.0	13.2	738	100.0	18.3
49	47	**NL Industries**	1,007	17.2	100.0	Basic chemicals	261	24.8	100.0	25.9	841	100.0	31.0
50	59	**Solvay America**	1,000[d]	17.6	100.0	Basic chemicals	na	na	na	na	na	na	na

Rank 1988	Rank 1987		Chemical sales 1988 ($ millions)	Change from 1987	Chemical sales as % of total sales	Industry classification	Chemical operating profits[a] ($ millions)	Change from 1987	Chemical operating profits as % of total	Operating profit margin[b]	Identifiable chemical assets ($ millions)	Chemical assets as % of total assets	Operating return on chemical assets[c]
51	49	**Nalco Chemical**	$994	18.1%	100.0%	Specialty chemicals	$159	21.2%	100.0%	16.0%	$ 839	100.0%	18.9%
52	51	**CF Industries**	958	18.3	100.0	Agrochemicals	110	2461.4	100.0	11.5	991	100.0	11.1
53	36	**International Minerals**[h]	932	−23.2	100.0	Specialty chemicals	117	12.9	100.0	12.5	1,050	100.0	11.1
54	52	**Cabot**[e]	904	13.0	53.9	Basic chemicals	163	33.4	121.4	18.0	665	43.1	24.5
55	55	**Morton Thiokol**[h]	874	17.4	37.7	Diversified	149	14.7	52.2	17.0	795	41.4	18.7
56	60	**Terra Chemicals**	849	25.0	100.0	Agrochemicals	na	na	na	na	na	na	na
57	54	**International Flavors**	840	12.6	100.0	Specialty chemicals	209	14.0	100.0	24.9	882	100.0	23.7
58	53	**Eli Lilly**	798	6.6	19.6	Drugs	126	48.9	11.3	15.8	787	15.0	16.1
59	64	**Vista Chemicals**[e]	781	28.3	100.0	Basic chemicals	195	63.3	100.0	24.9	521	100.0	37.4
60	68	**Farmland Industries**	767	46.2	27.3	Agricultural supplies	75	5838.7	66.7	9.8	324	44.5	23.1
61	63	**Witco**	758[g]	21.5	47.8	Specialty chemicals	62	2.2	43.0	8.2	361	32.4	17.2
62	67	**Uniroyal Chemical**	734	24.3	100.0	Specialty chemicals	86	17.2	100.0	11.7	1,016	100.0	8.5
63	57	**Engelhard**	727	2.0	30.9	Specialty metals	107	22.7	85.5	14.8	880	62.3	12.2
64	—	**Sterling Chemical**	699	69.2	100.0	Basic chemicals	312	246.4	100.0	44.7	294	100.0	106.1
65	66	**H. B. Fuller**[i]	685	14.7	100.0	Specialty chemicals	46	−2.8	100.0	6.8	421	100.0	11.0
66	61	**American Petrofina**	682	1.7	27.7	Petroleum	281	38.2	113.7	41.1	360	15.5	77.9
67	65	**Henkel**	650	8.3	100.0	Specialty chemicals	na	na	na	na	na	na	na
68	72	**Great Lakes Chemical**	558	16.6	100.0	Specialty chemicals	143	68.7	100.0	25.7	664	100.0	21.6
69	—	**Borden Chemicals**	553	na	100.0	Basic chemicals	121	−41.8	100.0	21.9	605	100.0	20.0
70	76	**GAF**	545	26.3	56.7	Specialty chemicals	150	15.4	83.2	27.5	na	na	na
71	73	**Kerr-McGee**	518	11.6	19.3	Petroleum	102	43.7	43.8	19.7	671	22.3	15.2
72	69	**Pfizer**	512	−0.2	9.5	Drugs	49	−29.7	4.4	9.5	489	6.4	10.0
73	75	**Tyler**	485	11.3	75.3	Diversified	37	1.3	85.0	7.6	202	65.7	18.3
74	76	**Merck**	466	8.1	7.8	Drugs	62	6.6	3.3	13.2	426	7.0	14.4
75	79	**Sun Co.**	461	24.4	4.7	Petroleum	na	na	na	na	na	na	na
76	—	**Hoffmann-La Roche**	450	4.2	23.7	Drugs	na	na	na	na	na	na	na
77	78	**Betz Laboratories**	448	16.0	100.0	Specialty chemicals	na	na	na	na	na	na	na
78	80	**Ferro**	443	22.3	43.9	Specialty materials	18	−34.8	17.7	4.1	242	45.8	7.5
79	88	**Dexter**	424	9.7	51.3	Rubber products	26	−28.1	28.3	6.1	298	47.6	8.7
80	83	**Loctite**	417	23.4	100.0	Specialty chemicals	66	45.1	100.0	15.8	347	100.0	19.0
81	82	**Union Camp**	398	14.3	15.0	Diversified	30	42.8	6.0	7.5	294	9.5	10.2
82	85	**Lonza**	395	26.6	100.0	Specialty chemicals	na	na	na	na	na	na	na
83	86	**Vulcan Materials**	383	28.5	36.3	Nonmetallic minerals	66	102.3	31.9	17.3	na	na	na
84	87	**Stepan**	333	15.3	100.0	Specialty chemicals	21	6.9	100.0	6.2	186	100.0	11.1
85	90	**Sigma-Aldrich**	302	22.1	80.5	Specialty chemicals	77	20.7	86.9	25.5	314	87.4	24.5
86	89	**Petrolite**[j]	274	10.4	91.0	Specialty chemicals	21	−1.2	127.5	7.7	186	76.7	11.4
87	84	**Chemed**	270	−19.6	54.0	Specialty chemicals	33	−19.0	66.6	12.4	133	48.3	25.1
88	94	**Georgia-Pacific**	241	27.5	2.5	Wood products	na	na	na	na	na	na	na
89	95	**First Mississippi**	237	31.2	74.6	Agrochemicals	23	190.0	101.4	9.8	104	34.6	22.3
90	92	**Crompton & Knowles**	232	21.8	80.2	Specialty chemicals	26	33.5	71.3	11.4	159	77.1	16.7
91	—	**Calgon Carbon**	226	32.5	100.0	Basic chemicals	51	30.6	100.0	22.6	196	100.0	26.1
92	—	**Sherex**	200	na	100.0	Specialty chemicals	na	na	na	na	na	na	na
93	96	**Mississippi Chemical**	186	6.6	100.0	Farm cooperative	18	def	100.0	9.8	322	100.0	5.7
94	97	**Quaker Chemical**	167	12.9	100.0	Specialty chemicals	17	3.5	100.0	10.4	121	100.0	14.3
95	99	**LeaRonal**[k]	157	23.0	100.0	Specialty chemicals	14	12.4	100.0	9.0	88	100.0	15.9
96	—	**Lawter International**	126	12.3	100.0	Specialty chemicals	27	11.5	100.0	21.8	125	100.0	21.9
97	100	**UGI**	124	6.7	28.5	Natural gas	4	200.8	6.9	3.6	168	27.2	2.6
98	98	**Agway**	123	−7.6	3.4	Farm cooperative	na	na	na	na	na	na	na
99	—	**Cambrex**	120	11.5	100.0	Specialty chemicals	13	−4.3	100.0	10.5	na	na	na
100	—	**Products Research**	100	5.4	100.0	Specialty chemicals	17	−11.7	100.0	16.6	68	100.0	24.6

a Operating profit is sales less administrative expenses and costs of sales. **b** Operating profit from chemicals as a percentage of sales. **c** Chemical operating profit as a percentage of identifiable chemical assets. **d** Chemical sales include significant amounts of nonchemical products. **e** Fiscal year ends Sept. 30. **f** Chemical net income. **g** Does not include all chemical sales. **h** Fiscal year ends June. 30. **i** Fiscal year ends Nov. 30. **j** Fiscal year ends Oct. 31. **k** For fiscal year ended Feb. 29, 1988. **na** = not available.

C&EN's five-way ranking of the Top 100 chemical producers

	Chemical sales			Chemical operating profits			Chemical operating profit margin			Identifiable chemical assets			Return on chemical assets		
		Rank			Rank			Rank			Rank			Rank	
$ Millions	1988	1988	1987	1988	1988	1987	1988	1988	1987	1988	1988	1987	1988	1988	1987
Agway	$ 123	98	98	na	—	—	na	—	—	na	—	—	na	—	—
Air Products	2,237	20	22	$ 409	19	16	18.3%	35	12	$2,462	14	14	16.6%	52	37
Akzo	1,347	37	40	76	58	—	5.6	80	—	na	—	—	na	—	—
Allied-Signal	3,033	15	12	377	22	20	12.4	55	55	1,839	18	15	20.5	37	43
Aluminum Co. of America	1,215	38	41	419	18	56	34.5	4	71	2,577	12	12	16.3	53	71
American Cyanamid	2,167	22	19	214	34	27	9.9	65	58	1,519	19	22	14.1	60	53
American Petrofina	682	66	61	281	29	26	41.1	2	2	360	57	61	77.9	2	1
Amoco	4,352	9	9	1022	6	6	23.5	17	10	2,920	9	8	35.0	10	8
Arco Chemical	2,700	17	19	722	12	11	26.7	11	9	2,548	13	29	28.3	17	14
Aristech	1,065	45	45	196	38	39	18.4	34	44	676	45	—	29.0	16	—
Ashland Oil	2,090	24	27	102	54	46	4.9	81	73	754	42	46	13.5	61	44
Atlantic Richfield	1,903	26	32	na	—	—	na	—	—	na	—	—	na	—	—
BASF	4,536	8	7	na	—	—	na	—	—	na	—	—	na	—	—
BP America	1,507	31	43	na	—	65	na	—	76	na	—	—	na	—	—
Bayer USA	2,140	23	20	na	—	—	na	—	—	na	—	—	na	—	—
Betz Laboratories	448	77	78	na	—	53	na	—	20	na	—	60	na	—	12
Borden Chemicals	553	69	—	121	49	—	21.9	22	—	605	50	—	20.0	39	—
CF Industries	958	52	51	110	51	78	11.5	59	79	991	33	33	11.1	64	73
Cabot	904	54	52	163	41	38	18.0	36	25	665	47	48	24.5	24	17
Calgon Carbon	226	91	—	51	64	—	22.6	19	—	196	67	—	26.1	20	—
Cambrex	120	99	—	13	81	—	10.5	61	—	na	—	—	na	—	—
Chemed	270	87	84	33	68	61	12.4	57	47	133	72	69	25.1	22	14
Chevron	3,204	13	16	616	15	13	19.2	30	25	2,101	16	18	29.3	14	15
Ciba-Geigy	1,098	43	28	na	—	—	na	—	—	na	—	—	na	—	—
Crompton & Knowles	232	90	92	26	71	73	11.4	60	56	159	71	73	16.7	51	21
Dexter	424	79	88	26	72	67	6.1	79	57	298	62	67	8.7	73	37
Dow Chemical	12,128	2	2	3655	1	2	30.1	7	17	10,792	1	1	33.9	11	19
Dow Corning	1,477	32	33	na	—	—	na	—	—	na	—	—	na	—	—
Du Pont	14,717	1	1	2612	2	1	17.7	37	19	10,290	2	2	25.4	21	11
Eastman Kodak	3,033	15	15	628	14	14	20.7	25	29	2,875	10	9	21.8	35	40
Eli Lilly	798	58	53	126	48	48	15.8	44	52	787	41	36	16.1	54	60
Engelhard	727	63	57	107	52	47	14.8	50	47	880	37	40	12.2	62	57
Ethyl	1,674	30	31	309	26	21	18.5	33	16	1,141	26	30	27.1	19	10
Exxon	9,990	3	3	1863	3	3	18.6	31	28	6,731	5	3	27.7	18	33
FMC	1,435	33	30	224	32	22	15.6	46	23	1,234	25	23	18.1	47	30
Farmland Industries	767	60	68	75	59	79	9.8	68	80	324	59	57	23.1	28	74
Ferro	443	78	80	18	76	68	4.1	82	69	242	65	66	7.5	75	44
First Mississippi	237	89	95	23	73	77	9.8	67	75	104	75	74	22.3	31	67
Freeport-McMoRan	1,130	41	46	198	37	42	17.5	38	46	894	35	38	22.1	32	44
H. B. Fuller	685	65	66	46	66	59	6.8	77	66	421	55	56	11.0	67	48
GAF	545	70	76	150	43	35	27.5	10	3	na	—	53	na	—	5
General Electric	3,539	12	14	733	11	8	20.7	24	15	7,130	3	6	10.3	69	56
Georgia Gulf	1,061	46	58	312	24	30	29.4	9	8	457	53	58	68.3	3	3
Georgia-Pacific	241	88	94	na	—	—	na	—	—	na	—	—	na	—	—
B. F. Goodrich	2,074	25	25	308	27	23	14.8	49	50	1,358	23	25	22.7	29	35
W. R. Grace	3,131	14	13	388	20	17	12.4	56	45	2,204	15	16	17.6	49	28
Great Lakes Chemical	558	68	72	143	45	48	25.7	13	17	664	48	47	21.6	36	47
Henkel	650	67	65	na	—	—	na	—	—	na	—	—	na	—	—
Hercules	1,750	27	26	141	46	33	8.1	72	68	1,376	22	24	10.2	70	66
Himont	1,711	28	—	524	17	—	30.7	6	—	1,044	30	—	36.8	8	—

	Chemical sales			Chemical operating profits			Chemical operating profit margin			Identifiable chemical assets			Return on chemical assets		
		Rank			Rank			Rank			Rank			Rank	
$ Millions	1988	1988	1987	1988	1988	1987	1988	1988	1987	1988	1988	1987	1988	1988	1987
Hoechst Celanese	$5,369	6	6	$ 563	16	—	10.5%	62	—	na	—	—	na	—	—
Hoffmann-La Roche	450	76	—	na	—	—	na	—	—	na	—	—	na	—	—
Huntsman Chemical	1,200	40	39	na	—	—	na	—	—	na	—	—	na	—	—
IMC Fertilizer	1,086	44	—	219	33	—	20.1	27	—	$1,472	20	—	14.8%	57	—
International Flavors	840	57	54	209	35	28	24.9	15	6	882	36	41	23.7	27	7
International Minerals	932	53	36	117	50	43	12.5	54	62	1,050	28	17	11.1	64	69
Kerr-McGee	518	71	73	102	54	50	19.7	29	25	671	46	49	15.2	56	57
Lawter International	126	96	—	27	70	—	21.8	23	—	125	73	—	21.9	34	—
LeaRonal	157	95	99	14	80	76	9.0	70	58	88	76	75	15.9	55	34
Loctite	417	80	83	66	60	60	15.8	45	41	347	58	59	19.0	42	41
Lonza	395	82	85	na	—	—	na	—	—	na	—	—	na	—	—
Lubrizol	1,036	47	44	306	28	31	29.6	8	30	730	44	42	41.9	6	18
Merck	466	74	76	62	62	58	13.2	53	41	426	54	52	14.4	58	55
Mississippi Chemical	186	93	96	18	76	81	9.8	66	—	322	60	64	5.7	76	—
Mobil	4,280	10	11	851	9	10	19.9	28	30	2,802	11	13	30.4	13	24
Monsanto	5,535	5	5	910	8	5	16.4	42	30	4,144	7	5	22.0	33	23
Morton Thiokol	874	55	55	149	44	35	17.0	40	21	795	40	39	13.7	44	25
NL Industries	1,007	49	47	261	30	24	25.9	12	7	841	38	35	31.0	12	6
Nalco Chemical	994	51	49	159	42	34	16.0	43	24	839	39	34	18.9	43	32
National Starch	1,415	34	37	200	36	29	14.1	51	35	1,110	27	31	18.0	48	25
Occidental Petroleum	4,673	7	10	1050	5	11	22.5	20	43	5,258	6	11	20.0	39	37
Olin	1,366	36	35	105	53	45	7.7	74	66	953	34	32	11.0	67	64
PPG Industries	1,113	42	42	255	31	31	22.9	18	33	1,048	29	29	24.3	26	54
Pennwalt	1,024	48	48	135	47	44	13.2	52	49	738	43	37	18.3	45	49
Petrolite	274	86	89	21	74	71	7.7	73	61	186	68	68	11.4	63	59
Pfizer	512	72	69	49	65	51	9.5	69	39	489	52	51	10.0	72	49
Phillips Petroleum	2,518	19	21	911	7	9	36.2	3	5	1,349	24	27	67.5	4	4
Products Research	100	100	—	17	78	—	16.6	41	—	68	77	—	24.6	23	—
Quaker Chemical	167	94	97	17	78	74	10.4	63	51	121	74	72	14.3	59	51
Quantum Chemical	2,219	21	23	711	13	18	32.1	5	14	1,465	21	21	48.6	5	13
Rhône-Poulenc	1,400	35	34	na	—	—	na	—	—	na	—	—	na	—	—
Rohm & Haas	2,535	18	17	377	22	19	14.9	48	33	1,857	17	20	20.3	38	20
Shell Oil	4,006	11	8	746	10	7	18.6	32	22	3,822	8	7	19.5	41	36
Sherex	200	92	—	na	—	—	na	—	—	na	—	—	na	—	—
Sigma-Aldrich	302	85	90	77	57	55	25.5	14	4	314	61	63	24.5	24	9
Solvay America	1,000	50	59	na	—	—	na	—	—	na	—	—	na	—	—
Stepan	333	84	87	21	74	40	6.2	78	1	186	68	70	11.1	64	2
Sterling Chemical	699	64	—	312	24	—	44.7	1	—	294	63	—	106.1	1	—
Sun Co.	461	75	79	na	—	—	na	—	—	na	—	—	na	—	—
Terra Chemicals	849	56	60	na	—	—	na	—	—	na	—	—	na	—	—
Texaco	1,711	28	29	379	21	37	22.2	21	65	1,029	31	26	36.8	8	63
Tyler	485	73	75	37	67	63	7.6	75	64	202	66	65	18.3	45	31
UGI	124	97	100	4	82	79	3.6	83	78	168	70	76	2.6	77	72
Union Camp	398	81	82	30	69	71	7.5	76	72	294	63	62	10.2	70	68
Union Carbide	7,601	4	4	1542	4	4	20.3	26	37	6,897	4	4	22.4	30	52
Uniroyal Chemical	734	62	—	86	56	—	11.7	58	—	1,016	32	—	8.5	74	—
Unocal	1,204	39	38	182	40	70	15.1	47	77	622	49	43	29.3	14	70
Vista Chemical	781	59	64	195	39	40	24.9	16	11	521	51	50	37.4	7	12
Vulcan Materials	383	83	86	66	60	64	17.3	39	54	na	—	—	na	—	—
Witco	758	61	63	62	62	57	8.2	71	60	361	56	55	17.2	50	28

Note: Companies giving only net profits are not ranked. There are 83 firms ranked for operating profits and operating profit margin and 77 firms ranked for chemical assets and return on assets. **na** = not available.

Companies new to Top 100 in 1988 . . .

	Sales rank 1988
Himont	28
IMC Fertilizer	44
Sterling Chemical	64
Borden Chemicals	69
Hoffmann-La Roche	76
Calgon Carbon	91
Sherex	92
Lawter International	96
Cambrex	99
Products Research	100

. . . and those no longer on list

	Sales rank 1987
Borden	24
Reichhold	50
Polysar	56
Koppers	62
Liquid Air	70
CBI Industries	71
Henley Manufacturing	73
Cain Chemical	81
Kaisertech	91
Essex Chemical	92

nual chemical sales totaled about $14.7 billion in 1988, about $2.6 billion more than sales at Dow Chemical, ranked second.

The sixth-ranked company in 1987, Hoechst Celanese, also appears in the same place in 1988, but after that there is a good deal of shifting. Seventh-ranked Occidental Petroleum moved up from 10th in 1987, causing BASF to drop to eighth. Ninth-ranked Amoco held the same place in both years, but 10th-ranked Mobil moved up from 11th in 1987's ranking. Eighth in 1987, Shell Oil fell all the way to 11th in 1988.

Of the companies that appeared on both the 1987 and 1988 lists, 49 moved up in the rankings, 27 declined in their rankings, and 14 held the same position. The biggest increases in rank were registered by BP America, which moved from 43rd in 1987 to 31th in 1988, and Georgia Gulf, which rose to 46th from 58th—both 12 places. BP America's rise is the result of the full consolidation this year of Standard Oil's business into BP. Georgia Gulf's rise stemmed primarily from improved business.

The two largest declines were recorded by Ciba-Geigy—15 places to 43rd from 28th—and by International Minerals—17 places to 53rd from 36th. The drop for Ciba-Geigy comes from a restructuring within the company and a revamping of its reporting methods. In 1988 not all of its chemicals sales are included, since its sales of pesticides are lumped with those of pharmaceuticals.

For IMC, as mentioned earlier, the drop in ranking resulted from the spinoff of IMC Fertilizer, which is new to the list in 1988 and ranked 44th. A similar situation occurred with Borden Chemicals & Plastics, also new on the list and ranked 69th. This firm was spun off from Borden, which disappears from the 1988 rankings.

Eight other firms are new to the 1988 rankings. Hoffmann-La Roche and Sherex, two foreign-owned firms that could have been included in the past, finally disclosed chemical sales for 1988. Himont can now be included because its results are no longer incorporated into Hercules (Himont's inclusion in previous listings would have resulted in double counting). And Sterling Chemical now makes its results public. The remaining four firms—Calgon Carbon, Lawter International, Cambrex Corp., and Products Research & Chemical—move onto the list because other companies have dropped off.

The restructuring of the chemical industry is readily apparent when 1988 results are compared with those of just a few years ago. In 1984, the first year with a comparable breakout, foreign-owned firms made up just 7% of total chemical sales of the Top 100 companies. By 1988, however this figure had grown to 13%. Firms classified as chemical companies—those with chemical sales making up more than 50% of total sales—also increased their percentage of the total, to 42% in 1988 from 39% of companies listed in 1984. Since petroleum and natural gas producing companies kept their percentage stable at about 24%, these increases came at the expense of firms classified as diversified and other, whose percentage fell to about 20% of the total for those companies listed in 1988 as opposed to 30% for the firms listed in 1984.

C&EN's rankings of the Top 100 includes measures other than sales. Companies are also ranked by chemical operating profits, chemical assets, and operating returns on sales and assets.

Growth in operating profits in 1988 for those firms reporting these figures averaged 54%. Among the larger 50 firms, growth in operating profits averaged 56%, far outperforming the 35% growth for the smaller 50 reporting these results.

The larger firms also outperformed the smaller in profitability. Operating profit margins among the larger 50 for which this can be calculated averaged 19% in 1988, up from 15% in the previous year. For these firms, the average operating profit margin was 17%, up from 14%. This gives an average for the group of 19%, up from 15%.

The same trend holds for return on chemical assets. Here the larger 50 firms averaged 25% in 1988, up from 19% in 1987. The smaller 50 companies averaged 19%, an increase from 15%. The average for the companies reporting both operating profits and chemical assets was 24%, up from 18%.

Although Du Pont is the sales leader among the Top 100, Dow Chemical is on top in both chemical operating profits and identifiable assets in 1988. Dow's $3.7 billion in chemical operating profits was more than $1 billion higher than Du Pont's operating profits and its identifiable chemical assets of $10.8 billion were about $500 million more than those of Du Pont.

Following Du Pont in operating profits were Exxon, Union Carbide, and Occidental Petroleum. And following it in chemical assets were General Electric, Carbide, and Exxon.

The leader in operating profit margin was Sterling Chemical at 45%. Sterling was followed by American Petrofina (41%), Phillips Petroleum (36%), Alcoa (35%), and Quantum Chemical (32%).

Sterling also was tops in operating return on assets with a phenomenal 106%, followed by American Petrofina (78%), Georgia Gulf and Phillips (68%), and Quantum (49%). □

8
ENGINEERING
NEWS

Chemical firms offer profit-sharing to more employees Page 17

Japan

The emerging shape of science and technology policy Page 7

CHEMICAL & ENGINEERING
NEWS

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MAY 8, 1989

News of the Week

- **Cold fusion work assailed during last week's meeting of the American Physical Society.** Page 4
- **Adding fluoride to drinking water seems to have little effect on tooth decay rates, according to new studies.** Page 5
- **President Bush's comments linking chemical makers to cocaine trade draw rebuttals from industry.** Page 6
- **AT&T's David McCall selected to head commission to recommend development, applications of superconductor technologies.** Page 6

Business

Major chemical producers offer profit-sharing wage packages to more employees; aerosol industry reports highest output figures since chlorofluorocarbon controversy began. Page 17

Government

Council on Research & Technology recommends ways federal, corporate joint efforts may improve science, technology education; proposed tax on chlorofluorocarbon sales raises questions. Page 22

Science/Technology

Bioconjugate chemistry, a field of recent advances and growing interdisciplinary interest, will be topic of ACS journal slated for publication in January; uses for membrane separators are forecast to grow; new organomolybdenum reagents for synthesis developed; emerging concept of carbon condensation examined; reformers elected as representatives of Soviet Academy of Sciences. Page 25

Education

Women remain underrepresented in chemistry faculties at Ph.D.-granting institutions. Page 34

Books

Consumers' guide to pesticides in fruits and vegetables makes some good points, but exaggerates risk-benefit relationship of use. Page 35

Cover: Photo by Lou Jones/Uniphoto Picture Agency

News Focus

Japan is globalizing its economy and industry, and leading that thrust are innovations in high technology and basic science, helped along by large infusions of capital. Page 7

Letters 2

Concentrates
Business 15
Government 21
Science/Technology 24

The Departments
ACS News 37
Meetings 42
Newscripts 60

Chemical & Engineering News

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LETTERS

Reader views on nuclear fusion

As of this writing, the claim of two chemists—B. Stanley Pons, University of Utah, and Martin Fleischmann, University of Southampton—to have "successfully created a sustained nuclear fusion reaction at room temperature" in a lab-top apparatus seems to be reeling under intense scrutiny from the scientific community. However the veracity of the Pons-Fleischmann claim is finally resolved, it has generated great excitement in the chemical community and intensified the letter-writing propensity of C&EN readers. Starting with this issue, the magazine will publish a wide sampling of such letters. Readers should note that because C&EN is a weekly news magazine and not a journal, the letters it carries are not peer reviewed prior to publication.

SIR: Since everyone else is rushing to get out their theories about how cold fusion works (or doesn't), I thought I should get mine into print as rapidly as possible to avoid being scooped. (I will reluctantly forego the immense riches that might possibly be attained by patenting it instead.)

When D_2O is electrolyzed at a palladium cathode (if it is done correctly—not every lab has been able to achieve this!), a new and unknown form of radiation is emitted. This radiation has the special property of affecting that portion of the brain where everything we have learned about the scientific method is stored. Scientists with previously impeccable credentials forget about control experiments, calibration, the careful exclusion of alternate explanations, etc., and call a press conference to explain (without any experimental detail, of course) what their half a day's worth of work means.

My theory is admittedly incomplete, but I think it explains the events of the past few weeks as well as or better than anybody else's. As a careful scientist, I will refrain from discussing whether the effect of this radiation upon the brain is reversible until more data are in.

Jay A. Labinger
California Institute of Technology

SIR: The ability of American science to quickly change gears and begin to exploit new ideas is an admirable trait. However, the haste with which many have moved to attempt cold fusion is unseemly at best, and at worst probably irresponsible.

We are repeatedly hearing talk of explosions and we are seeing experiments being performed by people whose backgrounds would suggest that they have little or no experience in the handling of radionuclides, or radiation in general. If newspaper reports can be believed, people are literally risking life and limb—at least of their graduate students and possibly of others—by undertaking experiments without adequate facilities or planning. This is not appropriate behavior for mature scientists, this is the behavior of little boys who just got a chemistry set for Christmas.

I think that the situation is particularly well demonstrated by the fact that many of these investigators were apparently surprised by the explosions. This surprise demonstrates that they did not even undertake a literature search before beginning experimentation. Even the most cursory examination of the literature will reveal that palladium cathodes are prone to explosions. See, for example, Moeller, T., "Inorganic Chemistry: an Advanced Textbook," (John Wiley, New York, page 411, 1952).

Since ethics in society is a current hot topic, I would also suggest that it might be most interesting to involve the Government Accounting Office in a study of just how this enormous new fusion effort is being funded. Although pure speculation on my part, I would be willing to place a fairly large bet that a very large percentage of principal investigators are funding this new work using granting agency funds that were appropriated with no mention whatever of the word fusion or even the words "new energy sources." I will also bet that many of these principal investigators will write annual progress reports that somehow fail to describe how they diverted their graduate students away from granting-agency goals for a large part of the year.

In short, should we be wondering just how much of this new work amounts, in a strictly legal sense, to simple misappropriation of funds? There is no question that our scientific establishment needs to have some flexibility, but I think we should seriously question whether it is advisable and proper to obtain that flexibility by bending the rules and thereby teaching our graduate students to bend the rules.

I think that we should all consider the message we send to society at large, when we implicitly condone such improper behavior from our most preeminent scientists. Are we not saying to the

Companies Offer Profit-Sharing Packages to More Employees

Major chemical producers hope to increase employee participation through incentives based on company performance

Ann M. Thayer,
C&EN Northeast News Bureau

New jargon is cropping up in descriptions of employee benefits from some of the major chemical companies. Phrases such as "quality processes," "contingent compensation," and "variable pay" are occurring more and more frequently. However, the meaning of these terms and how they relate to real paychecks may not be clear to some. And although it appears that sizeable gains may be possible, there may also be some sizeable risks. The consequence is that salaries will be linked to new roles for all levels of employees in industry.

In the past decade, industry in general has been turning toward the use of contingent compensation, programs that link employee compensation to the performance of the business. The results of a survey by Hay Group, a Philadelphia-based management consulting firm, indicate that the chemical and pharmaceutical industries are beginning to put such programs in place. But they lag the rest of industry in incentive programs for small groups and gain-sharing plans based solely on productivity. However, special payments to individuals for significant contributions to the company are prevalent in the chemical industry.

It is not surprising that companies are moving toward contingent compensation. Mature, technology-based industries may find that increased profitability will come about only through increased productivity and cost-containing measures. Although the chemical industry is currently in the midst of a boom, increased costs, capacity additions coming on-line, and smaller increases in earnings might lead to a bust in the early 1990s. With the massive terminations of the early 1980s behind them, Hay Group says, U.S. businesses are committing themselves to controlling the base salary levels of their existing work forces and to introducing more variable pay programs.

"There is really a change in mentality toward pay," says Steven E. Gross, vice president and general manager of Hay Management Consultants, a division of Hay Group. "As companies reposition themselves for the 1990s, they are leaner and meaner, with fewer layers of middle management, and they are trying to make the pay system support some of their cultural changes of the past few years." These changes include an emphasis on employee participation to increase productivity and profitability and a shift away from an "entitlement attitude" on the part of employees toward pay increases.

Steel: company performing better

Employee incentives through profit sharing generally take the form of a cash bonus, the amount of which is linked to earnings growth, return on investment, or other measures of a company's performance. "Employees have to believe that they can make a difference and can impact on the measurement," comments Gross. "They have to understand the measurement and accept that it makes sense,

Chemical industry lags in incentive programs

	Industry in general[a]		Chemicals/pharmaceuticals[b]	
Program type	In place by September 1988	Considering	In place by September 1988	Considering
Gain sharing[c]	14%	23%	5%	14%
Profit sharing[d]	29	12	35	5
Small group incentives	25	24	11	11
Lump-sum payments[e]	26	22	27	16
Key contributions by individuals	34	21	70	5

a 952 companies. b 41 companies. c Bonus based on increased productivity. d Bonus based on company's financial performance. e One-time payment in lieu of salary increase. **Source:** 1988 Hay Management Compensation Conference Survey or you will not get the changes you are looking for." Gross believes that it is important to have a plan include all levels of employees, from management to the hourly worker to support staff.

To have a promising incentive program, it should be carefully designed and implemented. Gross explains that a company should communicate the details and aim of the program effectively, set a reasonable goal, and determine an equitable size for a group of participating employees. "The best measurement is based on the smallest unit," says Gross, "but in the chemical industry, where it is so process-oriented and the integration is much greater, it makes sense to choose somewhere between an individual and the entire company, or the employees will suffer a lot of factors outside their control."

Gross worked with a team from Du Pont to help design an "achievement sharing" program for its fibers department (C&EN, Nov. 7, 1988, page 8). The department, Du Pont's second largest in sales, had nearly $6 billion in sales and more than $700 million in earnings in 1988. It is made up of about 25 businesses with 20,000 employees, trimmed down from 27,000 in the mid-1980s, whose performance is being gauged together under the program. Robert P. McNutt, a fiber-marketing executive who leads Du Pont's team, believes that having the program encompass the "larger whole" rather than separate business units was the fairest way in which to set attainable goals.

Under the plan, 6% of employees' salaries is at-risk, and an annual goal of 4% real growth in earnings is set for the department. If the goal is reached, which is not unreasonable based on past performance, employees will get back the 6%, receiving the full 100% of their salaries. When levels up to 150% of the goal are reached, the company is prepared to pay employees as much as an additional 12% of their salary base. Employees receive only 94% of their salary, losing the 6% at-risk, when 80% or less of the goal is met. It is not inconceivable that the department can be making a profit, even with growth in earnings of less than 4%, yet employees will lose 6% of their pay. For Du Pont, this would save the company tens of millions of dollars.

Doyle: folks now look at bottom line

The driving forces behind variable pay plans are really changes in attitude rather than attempts to control costs, suggests Gross, although the latter would help in the event of a business downturn. He points to the great upside potential for employees and the willingness of companies to share in profits. Despite the potential for healthy bonuses, critics question whether employees will be taking it on the chin in hard times, forfeiting a percentage of their salaries, while the financial blow to companies is somewhat lessened.

Du Pont's program is being implemented incrementally as of Jan. 1, 1989. This means that, over the next three to five years, 2% (at most) of an individual's salary is taken from pay increases and put into the plan. McNutt indicates that the plan is "building momentum." Having salary at-risk is a very important part of the program, as it "reinforces a feeling of ownership and really gets people's attention."

To initiate the program, a voluntary accelerated participation option was offered in October 1988 to allow people to become vested early. McNutt was surprised to find, and considers it a vote of confidence, that more than half of the department's employees agreed to have an initial 2% of their salaries put at-risk. Separate from this option, an incentive payment reflecting what would have been received had 2% been placed at-risk in 1988 was given in February 1989 to all employees eligible for the program. With growth in earnings reaching 4.5% in 1988 (112.5% of the goal), employees received a bonus equal to 3% of their salaries.

It is still a bit early to tell whether Du Pont's or any other chemical company's profit-sharing program has had the desired results. Currently, these programs are being set up when times are good and employees may expect to receive their salaries or slightly more. Although the potential monetary returns are expected to motivate employee behavior, the chemical industry has yet to go through a downturn and to see any repercussions when employees lose money put at-risk.

People need time to adjust to changes, comments McNutt, especially older employees who are accustomed to more traditional forms of compensation. He emphasizes that a change in pay policy should support or reflect changes already occurring in the environment of the company and not vice versa. These changes can include redirecting attitudes toward quality performance, increasing employee participation, and/or opening up channels of communication.

Union Carbide has taken a similar attitude toward its corporate environment with an "excellence through quality" program in its chemicals and plastics group. The group was formed about a year and a half ago to combine Carbide's chemical businesses. As part of the new alignment and to further unite employees, a profit-sharing program has just recently been introduced. "This is the basis of our beginning to think of [the group] as a total entity," says Lawrence F. Doyle, human resources vice president of the group. "The genesis of our incentive-pay plan is really our excellence through quality process," he adds. "It's an attempt to tie our compensation strategy to the very things we are trying to do from a management perspective."

Carbide's profit-sharing program

covers 14,000 employees including the group president and some union employees. On April 1, employees received a one-time payment equal to four weeks' pay. At that time, they began foregoing 1989 wage and salary increases. This will continue until pay levels are 5% below what they would have been without the plan—5% amounts to about $25 million of the company's payroll.

When the chemical and plastic group's performance meets its target of a 12% return on capital, the employees break even. (Return on capital is the ratio of sales, less operating expenses and taxes, to assets and investments in the business.) The program kicks in at an 8% return, equivalent to $100 million in operating profits per quarter, below which the employees forfeit the 5% of salary at-risk. A maximum bonus of 10% of salary is awarded with a 22% return on capital, or about $280 million in earnings per quarter.

Returns will be reported on a quarterly basis to the employees and payments will be made each February. "We now have five excellent opportunities every year when employees are going to be very much interested in what is going on in the business," says Doyle. "The whole plan is predicated upon that and, with 14,000 folks looking at the bottom line, we know we are going to make an impact on business.

"We recognize that the marketplace for commodities has an awful lot to do with good times and bad times, but, even within that, we believe that the leverage from getting our employees heavily involved and invested in this plan can make a difference of 2 or 3% on our return on capital."

In addition to offering employees "homeowner" stakes in the company, rather than "tenant" status, profit-sharing programs are also being touted as a new form of personal job security. "In addition to what we hope we'll be sharing in the good times, we hope to be able to moderate our salary decreases, or freezes, or even terminations in bad times by virtue of having our fixed costs lower by 5%."

In considering all the same factors, Occidental Chemical decided instead to introduce a plan that does not require the employees to put any of their salary at-risk. Whereas many companies feel that the risk factor is a necessary incentive, J. Roger Hirl, president and chief operating officer of Occidental Chemical, believes otherwise. "By not putting any compensation at-risk, I think we have avoided the negative part of this thing that might occur in a downturn.

"The decision to proceed with a program was based not only on the fact that the performance of the employees was very good in 1988, but also that over a five-year period our chemicals unit has had very, very significant growth." Much of this growth was due to acquisitions by the company. Occidental Chemical's reward-sharing program includes about half of the 15,000 employees in all its chemical operations—Oxychem and Cain Chemical.

When return on investment reaches 20% for the company, nonunion employees will receive a cash payment equal to 10% of their salary. The program is capped at a level of 30% return-on-investment which yields a 20% bonus. The program was implemented for the calendar year 1988 and paid employees a bonus of 16.4%, based on a 26.4% return on investment—a sizeable, yet not unusual, return for the company.

Hirl believes that even in a highly technical and process-oriented industry such as chemicals, incentive programs that give employees a "stakeholder" interest in the corporation can work. "By containing costs, and improving efficiency and productivity in every facet of the company, the employee gets a share of the benefits." In addition, notes Hirl, management benefits from employee initiative, increased self-management, and a greater focus on common objectives. "I don't mean to suggest that this [kind of program] works in any other corporation," says Hirl, "but in our organization it is something that works well."

In November 1988, Hoechst Celanese announced a similar, companywide performance-sharing plan for its 22,000 employees, to be effective for all of 1988. "One of the very

Employees can win and lose in sharing programs

Four major chemical companies have implemented programs that provide employees with a means to share in the earnings of the business. Employees will receive cash payments, equal to a percentage of their salaries, if the goals set for the performance of the company are met. In some cases, if performance levels are not met, that portion of the salaries put at-risk would not be paid. The programs summarized below are open to all levels of salaried and wage-earning employees; union employees often participate in these plans once negotiations include them in contracts.

Company (unit)	Number of employees	Plan name	% salary at-risk	Potential salary return	Conditions for return
Du Pont (fibers)	20,000	Achievement sharing	6%	−6 to 12%	80 to 150% of 4% growth in earnings[a]
Union Carbide (chemical and plastics)	14,000	Profit sharing	5	−5 to 15	8 to 22% return on capital[b]
Occidental and Cain Chemical	7,500 to 8,000	Reward sharing	0	10 to 20	20 to 30% return on investment
Hoechst Celanese	22,000	Performance sharing	0	0 to 7	75 to 125% of undefined profit goal

a 6% of salary at-risk recovered when 100% of goal met. b 5% of salary at-risk recovered with 12% return on capital first decisions that was made by our newly merged corporation had to do with what will be our policy as it relates to compensation," says Hoechst Celanese's vice president for administration Gene Steel. The overall emphasis on performance and quality after the merger of Celanese and American Hoechst resulted in, says Steel, "our company performing better than it otherwise would have. Our commitment is to share with our employees as we see these improvements in performance."

Hoechst Celanese's plan does not require the employees to put any salary at-risk. Employees can receive cash rewards equal to 0 to 7% of their salary when the company reaches 75 to 125% of its earnings growth target. Although the company declines to identify specific figures for the target, the measure is based on internal indicators and profits, and reportedly takes into account all costs, assets, inflation, and the marketplace in an attempt to set a realistic goal. In 1988 the company reached its objective and paid 7% to each employee for a companywide total of more than $40 million.

Hoechst Celanese and Occidental Chemical have not changed their current compensation policies, adding their bonus plans on top of cost-of-living or individual merit-based salary increases. Carbide will return to a more usual compensation policy once its plan is in effect. All four companies, especially those like Du Pont with plans that put pay at-risk, indicate that they will keep base-pay levels competitive with the rest of the chemical industry.

The Hay Group survey indicates that average salary increases in the chemical and pharmaceutical industries for 1989 for all levels of management will be in the vicinity of 4.5%, about 0.5 to 1% below overall industry averages. Thus, through profit-sharing programs, employees have the potential to do better, but also worse, than they would with an average raise. Observers of the industry are waiting to see if wages and associated benefits rise more slowly in the future since the bonuses are not compounded into base-pay levels. □

Aerosol output rises again, tops '73 level

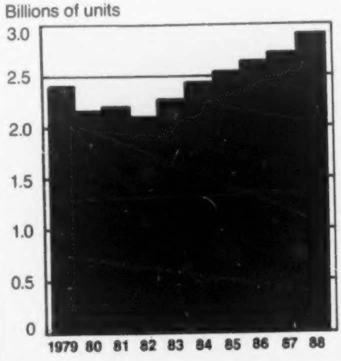
The 3 billion unit year still eludes the U.S. aerosol industry, but just barely, according to the latest annual pressurized products survey from the Chemical Specialties Manufacturers Association. At CSMA's midyear meeting in Chicago, survey committee chairman Daniel P. Minogue, vice president of sales for Precision Valve, revealed that an estimated 2.91 billion container units were filled in 1988, up 6.8% from 1987.

The increase marks the sixth consecutive year of real growth for the industry. It's also notable that production has finally returned to—and slightly surpassed—1973 levels. Aerosol output peaked that year at 2.90 billion units. Then it went into decline in the aftermath of the ozone-chlorofluorocarbon controversy, bottoming out at 2.10 billion units in 1982.

Among the various product categories, personal care products continued to be the largest, accounting for about 38% of the total. The committee estimates that 1.1 billion units of personal care products were filled last year, an increase of 14% from 1987. Minogue notes that a proliferation of new eye care products helped fuel growth in the category.

Household products, the perennial runnerup, accounted for 22% of the total. In contrast to the healthy growth in personal products, however, the 650 million units filled in the household products category represented only a 1.6% increase from 1987.

Aerosol production rose 6.8% in 1988



Source: Chemical Specialties Manufacturers Association

The category showing the greatest year-to-year percentage increase was the third place automotive and industrial products category. At 440 million units filled, representing 15% of the total, it was up 16% from 1987.

There may be a partial explanation for the apparently strong year for auto and industrial products and the apparently flat year for household products. Minogue points out that participants received new and detailed reporting instructions for the 1988 survey. For instance, all lubricants were to be included in the automotive and industrial products category. Thus, 1988 numbers for that category probably included lubricants formerly reported as household products.

Paints and finishes came in fourth. The 331 million units filled in that category accounted for 11% of the total and represented a 7.8% increase from 1987.

Food products also showed a healthy increase. Total fillings for 1988 amounted to 157 million units (5.4% of the total), up 12% from the preceding year. Pan sprays, cheese-like products, and "whipped" dessert toppings were among the major items in the category.

Of the other product categories, insect sprays accounted for 190 million units (6.5% of the total), essentially unchanged from 1987. The definition for that category was changed to exclude products used directly on animals. So it's likely that products formerly listed as insect sprays were counted as animal sprays in the 1988 figures.

Despite the change in classification, the animal products category dropped precipitously in 1988. Only 8 million units were filled, a figure that is down 64% from 1987. Similarly, the miscellaneous category was down sharply to 30.6 million units filled, a 62% decrease from 1987. Again, that's partly because products formerly reported as miscellaneous are now included in other categories.

Ward Worthy

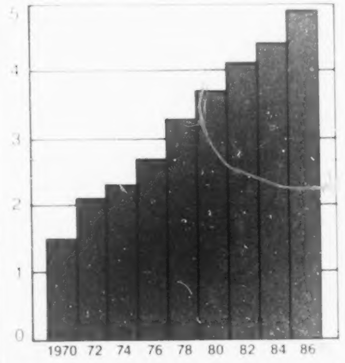
Female Chemistry Faculty Numbers Remain Low

The toehold that women have in the faculties of Ph.D.-granting chemistry departments continues to grow. But it is still only a toehold—an average of slightly more than one per department. And women are still underrepresented in the ranks of new members joining these faculties.

These are the major findings that can be gleaned, or inferred, from the latest survey by the American Chemical Society's Women Chemists Committee of tenured and tenure-track faculty positions in graduate chemistry departments. The study reveals that in 1986 women held 4.9% of such positions, 218 of a total of 4453. This compares with 4.4% two years earlier, 189 of a total of 4327, and indicates that less than 10% of new hires between 1984 and 1986 were women. Women have earned about 20% of chemistry Ph.D. degrees in recent years.

Data for the new study, which is the latest in an every-two-year series dating back to 1970, were compiled from information provided by chemistry departments to two ACS publications, the Directory of Graduate Research 1987 and College Chemistry Faculties (7th Edition, 1986). The study was prepared by Kathleen M. Trahanovsky, a member of the Iowa State University chemistry faculty, and Doris C. Lorz, emeritus professor at Southwest Missouri State University.

Women still less than 5% of chemistry faculties



a Percentage of women holding tenured or tenure-track positions on faculties of Ph.D.-granting chemistry departments. **Source:** Report prepared for ACS Women Chemists Committee

The new report quantifies the steady, if still modest, overall progress that women have made in penetrating graduate chemistry faculties in the longer term. In 1970, only 61 of 4091, or 1.5%, of tenured and tenure-track positions were held by women. Also, the number of departments with no women has declined from 76% in 1970 to 35% in 1986. But even in 1986, only 32% of the departments had at least two women members and were thus free of any possible charge of having, at most, a single, token woman.

Women do somewhat better in the chemistry departments of B.S.- and M.S.-granting institutions. The new study indicates that women held about 11.2% of tenured or tenure-track positions at these departments in 1986. This is up only very slightly from 11.0% in 1984. And it is down from the 12.0% reported for 1965 by the Women Chemists Committee.

The largest proportion of women in a graduate chemistry department in 1986 was at the University of Idaho, with three of 13. The department with the most women, seven, was that at the City University of New York (CUNY). Second, with five, was Rutgers University, New Brunswick. The buildup of women at CUNY has occurred since 1976. Rutgers has long had a relatively high number of women, with four in 1970 and a high of seven in 1974.

Women in appreciable numbers are relatively new to the four departments with four women in 1986—the University of California, San Diego; Mississippi State University; the University of Minnesota; the University of California, Berkeley; and the University of Delaware. With the exception of the University of Delaware, all these faculties were all-male in 1970. Delaware had one woman in 1970.

The largest all-male graduate chemistry faculties in 1986 were the University of Wisconsin, Madison, 37, and Arizona State University, 34.

Michael Heylin

These chemistry faculties had no women[a] . . .

School	Total faculty
U of Wisconsin, Madison	37
Arizona State U	34
Northwestern U	30
U of Utah	30
Virginia Poly Inst	29
Georgia Inst of Tech	28
Notre Dame U	28
San Diego State U	27
U of Georgia	26
U of South Carolina	26
Oregon State U	25
U of Virginia	25
U of Iowa	24
Yale U	24
U of Arkansas	23
Washington U, St. Louis	23

. . . these had three or more female faculty members[a]

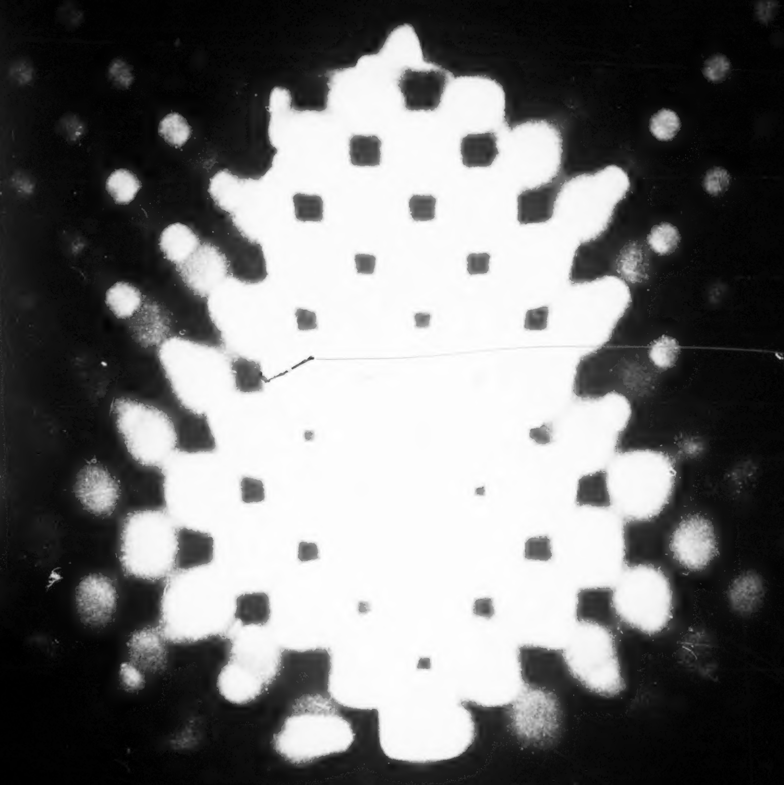
School	Faculty Total	Faculty Women
City U of New York	81	7
Rutgers U, New Brunswick	41	5
U of California, San Diego	43	4
Mississippi State U	33	4
U of Minnesota	41	4
U of California, Berkeley	58	4
U of Delaware	30	4
U of Maryland	47	3
U of North Carolina	35	3
Rensselaer Poly Inst	31	3
U of Idaho	13	3
Poly Inst of New York	17	3
American U	18	3
U of Puerto Rico	19	3
Utah State U	25	3
U of Oregon	27	3
U of Michigan	37	3

a In 1986–87. **Note:** University of Massachusetts Associated Five-Year Graduate Faculty had six women, out of a total of 26.

Chemical company earnings continue to rise in first quarter
Page 9

MAY 15, 1989

CHEMICAL & ENGINEERING NEWS



Diamond Thin Films

Page 24

Volume 67, Number 20
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CHEMICAL & ENGINEERING NEWS

MAY 15, 1989

News of the Week

- **Launch of Magellan spacecraft from shuttle for voyage to Venus kicks off new era of planetary exploration.** Page 4
- **Federal judge overrules as too strict the standards used to deal with claims of agent orange damage to Vietnam veterans.** Page 5
- **Electrochemical Society meeting hears replay of the conflicting results obtained by scientists running cold fusion experiments, and some admissions of error by Utah electrochemists.** Page 5
- **Sterling Drug will move most of the scientists and support staff at its Rensselaer, N.Y., research facilities to a Pennsylvania site; about 150 positions will be eliminated.** Page 6
- **Another study, this time from a Senate subcommittee, is strongly critical of EPA's implementation of its Superfund program.** Page 6

Business

Earnings of major U.S. chemical firms increased an average 22% in the first quarter, still substantial but lower than in previous quarters. **Page 9**

Bayer USA head Konrad Weis, 1989 Palladium medalist, reflects on Bayer's growth in the U.S. market, plans for the future. **Page 13**

Changing global operating environment is pushing chemical companies toward globalization. **Page 15**

Steel treatment firm Meridian National is branching into acid waste treatment business. **Page 16**

Government

Conferees at forum on global climate change urge international efforts to deal effectively with climate issues and to ward off potential environmental disasters. **Page 18**

Education

First ACS satellite teleconference course on synthetic polymer techniques airs, four-hour session reaches 1000 at 43 North American sites. **Page 21**

Science/Technology

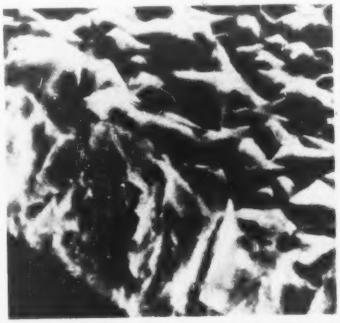
Research on catalytic converters for autos has led to a decrease in hydrocarbon, nitrogen oxides pollution and to a better understanding of noble-metal catalysis. **Page 23**

Cover: Closeup view of microwave plasma used to produce diamond thin films at Penn State's Materials Research Laboratory. Photo by Bruce Frisch

Letters 2

Concentrates
Business 7
Government 17
Science/Technology 20

The Departments
Meetings 43
Newscripts 58



Special Report

Advances in material sciences are paving the way for use of synthetic diamond in thin film coatings that confer on the coated material the hardness and the electronic and optical properties that only diamond has. **Page 24**

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LETTERS

Views on nuclear fusion

SIR: Your editorial (C&EN, April 3, page 3) regarding the need for the scientific community to address the problem of acceptable ways for communicating interesting results to the press (science and other) is extremely important.

In passing, however, it must be noted that B. Stanley Pons and Martin Fleischmann were veritable paragons of model behavior compared with what happened in the high-T_c superconductors. Indeed, even the science and secular press were much more restrained, partly because they themselves had been very careless in how they handled the superconductor hype emanating from some universities. The code that I proposed after that sorry episode was as follows:

- Major scientific societies agree, and publish a notice, that they will in no case publish (in any of their journals) any paper describing research that has been released to the press before a scientific paper has been submitted to the journal. Copies of the preprint must be available upon request from that time on. The submission requirement is the only workable one, since once submitted the result is public anyway. Neither the society nor referees are held to any confidentiality.
- Major newspapers and scientific publications agree not to print any such stories if no submitted preprints are available with them. These publications also clearly separate in their stories any report on the scientific results from any analysis or speculation of future potential of resulting technologies, etc. Moreover, they should take the utmost care that such analysis be evenhanded with optimistic and pessimistic views of named experts both presented. Here again, the fusion reports have been much more modest compared with the systematic suppression of any cautionary views in the high-T_c superconductor case.

The other issue certainly for a scientific journal and at least society science magazines in the case of such step-function advances is to be careful about giving proper credit to antecedent and/or parallel work, especially if it is foreign. To the best of my very limited knowledge in the fusion story, this was also better handled. Even so, it is interesting to remind your readers that room-temperature lab-scale neutron production was reported in a Soviet journal in 1986.

Please keep up the pressure on our collective scientist conscience to devise some guidelines to protect the public from this kind of "soft cheating," which is in many ways much more prevalent and more damaging to society than the more notorious but probably much rarer painting of mice and other kinds of fraud.

Rustum Roy
Evan Pugh Professor of the Solid State
Pennsylvania State University

SIR: I am writing to propose an explanation for the thermal effects reported in the room-temperature fusion experiments that have science in an uproar.

Finding energy released from the device to be four times greater than that supplied by the electrical source appears to be a violation of the first law of thermodynamics unless nuclear phenomena are considered. Another logical explanation is found, however, in the second law.

The energy supplied is "work." That discharged is "heat." A heat pump is capable of delivering an amount of heat at the hot junction that is many times greater than the work provided. The maximum theoretical ratio of heat to work depends on the absolute temperature and the difference in temperature between the heat source and the sink.

One of the simplest of heat engines is the "thermocouple," which consists of two different electrical conductors joined at both ends and having a switch somewhere in the circuit. If one junction is heated above the other and current is allowed to flow, electrons passing from conductor A to conductor B at the hot junction absorb heat. Electrons pass from B to A at the cold junction and heat is discharged. A net electromotive potential is generated in the circuit, and the system is capable of performing work. This phenomenon is known as the Seebeck effect. The first law requires that heat absorbed at the hot junction exceed that delivered by the cold one. Heat absorbed must also be considerably greater than the work output. Thermocouples are most commonly used to measure temperature differences by monitoring the open-circuit voltage, but the same scheme can be used to convert heat to work with the device operating as a heat engine.

Electrical current in the thermocouple can, of course, be reversed. Then, work must be supplied, heat is absorbed at the cold junction and is discharged at the hot junction. It now becomes a heat pump or refrigerator, depending on one's perspective. The theoretical ratio of heat discharged to work provided in a

Growth in Chemical Earnings Slows in First Quarter

Rising raw material costs plus failure of prices to keep pace are beginning to squeeze many U.S. chemical producers

William J. Storck,
C&EN Northeast News Bureau

Not so long ago a 22% increase in earnings would have been cause for the U.S. chemical industry to celebrate. But now, after a number of heady quarters for the industry, such a rise represents a considerable slowing of growth.

In fact, 22% is the lowest increase since the third quarter of 1986. This growth rate was the average for 30 major U.S. chemical companies regularly surveyed by C&EN in its quarterly report of chemical industry sales and earnings. Earnings growth slowed for many oil and diversified companies as well.

The slowdown in earnings is not to say that business was bad in the first quarter this year. The government's producer price index for chemicals and allied products increased 11% on average in the quarter over the same period in 1988. And production of chemicals and allied products was up about 8.5% for the quarter. However, this represents a slowing from the 8.9% annual growth recorded in the fourth quarter of 1988.

Further, growth in the demand for chemicals, although still high, seems to be slowing from last year. Government figures show that shipments of chemicals and allied products for the first quarter increased about 8.6%, down from 13% growth in fourth-quarter 1988 and from 13% growth for all of last year. The same pattern holds true for basic chemicals, where first-quarter shipments were up 8.3% from the same period a year earlier. In the fourth quarter, basic chemical shipments increased 9.0% on average and about 10% for all of 1988.

Though business was good in the first quarter, margins shrank for many companies producing downstream chemical products because raw material costs were rising faster than selling prices. For instance, H. B. Fuller Co., whose profits plummeted 59% in the quarter, says, "A significant decline in margins due to raw material cost increases was experienced in the first quarter. Pricing action has been taken to rectify the situation and margin improvement is noted from the fourth quarter of 1988."

American Cyanamid also notes a cost-price problem in its chemicals group. However, it says that the situation appears to be improving from the latter part of 1988. At Monsanto, which also notes the problem, chairman and chief executive officer Richard J. Mahoney believes that raw material costs have peaked.

Some companies see things differently, however. At Union Carbide, for instance, where earnings almost doubled, Robert D. Kennedy, chairman and chief executive officer, says that sales volume continues to be strong and the company continues to benefit from favorable raw material costs.

Also companies note that plant startup, increasing employment, and other operating expenses were

Chemical industry leaders for first-quarter 1989

Sales

Rank 1989		$ Millions	Rank 1988
1	Dow Chemical	$4485.0	1
2	Monsanto	2265.0	2
3	Union Carbide	2241.0	3
4	W. R. Grace	1397.2	4
5	American Cyanamid	1231.6	5
6	Quantum Chemical	814.1	6
7	Ethyl	729.1	8
8	Arco Chemical	699.0	11
9	Hercules	681.6	7
10	Rohm & Haas	679.5	9

Earnings[a]

	$ Millions	Rank 1988
Dow Chemical	$743.0	1
Monsanto	222.0	2
Union Carbide	201.0	4
Arco Chemical	116.0	3
American Cyanamid	89.0	6
Quantum Chemical	71.4	5
Air Products	56.6	8
Ethyl	56.4	9
Georgia Gulf	55.4	13
Rohm & Haas	53.1	7

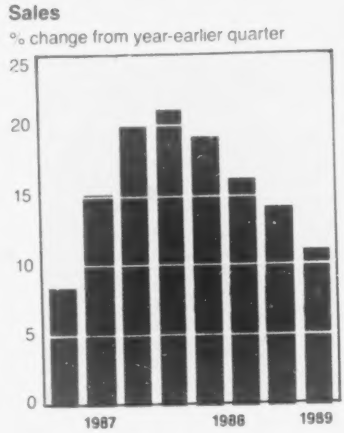
Profitability

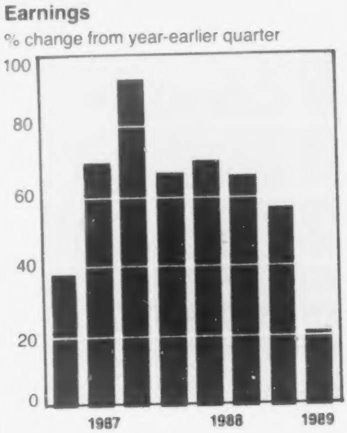
	Earnings as % of sales	Rank 1988
Great Lakes Chemical	19.7%	nr
Georgia Gulf	17.4	3
International Flavors	16.9	4
Arco Chemical	16.6	2
Dow Chemical	16.6	7
Vista Chemical	16.4	5
Aristech	13.3	1
Loctite	12.1	13
Betz Laboratories	10.6	8
Nalco Chemical	10.1	8

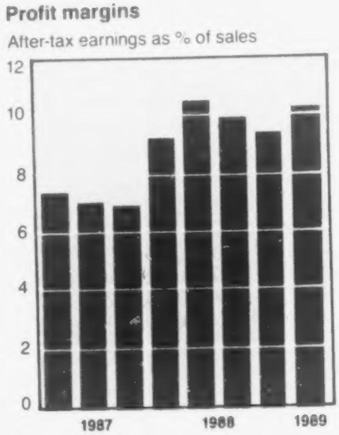
Note: Based on 30 chemical companies listed on page 11. a After taxes. nr = not ranked.

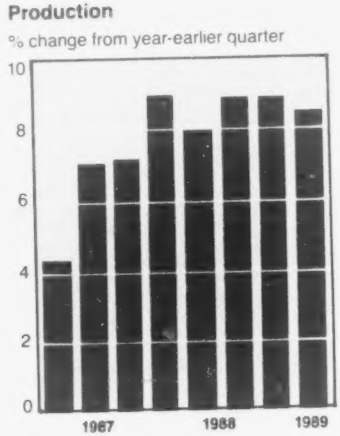
Chemical industry 1989 first-quarter results

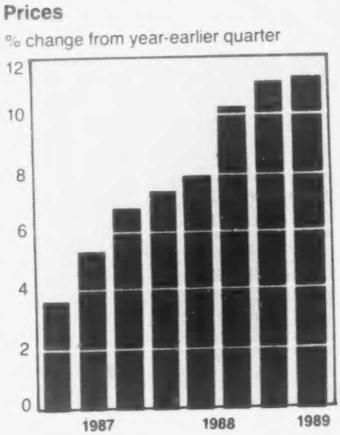
- **Sales increased 11%**
- **Earnings climbed 22%**
- **Profit margins were 10.1%**
- **Production rose 8.5%**
- **Prices jumped 11%**



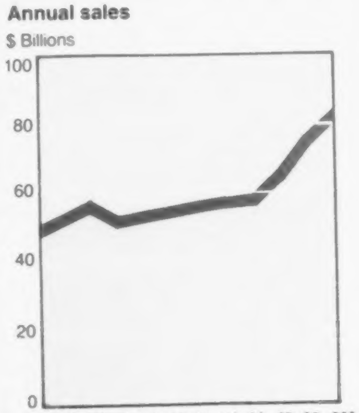


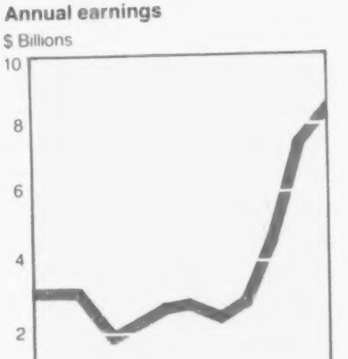


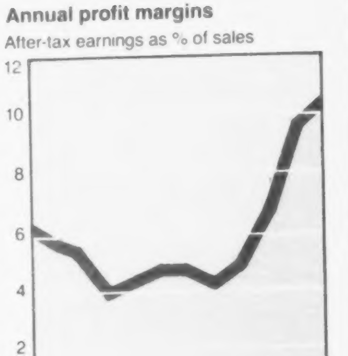




Sales in 1989 will rise about 8% and earnings will increase 15%, boosting profit margins to 10.4%







Note: All sales, earnings, and profit-margin data are based on combined results of 30 companies listed on page 11. a C&EN estimates

Sales and earnings continued to increase in first quarter

	FIRST-QUARTER 1989						12-MONTH RUNNING DATA			
	Sales	Earnings[a]	Change from 1988		Profit margin[b]		Change from 1988		Profit margin[b]	
	($ millions)		Sales	Earnings	1989	1988	Sales	Earnings	1989	1988
Air Products[c]	$ 668.9	$ 56.6	8%	2%	8.5%	9.0%	11%	15%	8.7%	8.4%
American Cyanamid[c]	1,231.6	89.0	7	12	7.2	6.9	9	17	6.7	6.3
Arco Chemical[c]	699.0	116.0	20	7	16.6	18.5	35	59	17.8	15.1
Aristech	275.2	36.5	6	−31	13.3	20.2	11	88	13.7	8.1
Betz Laboratories	124.4	13.2	18	18	10.6	10.6	16	20	10.8	10.4
Cabot[c]	540.9	29.0	16	56	5.4	4.0	22	28	3.9	3.7
Chemed	141.9	5.3	42	17	3.7	4.6	36	6	4.0	5.1
Crompton & Knowles	87.8	5.3	57	43	6.1	6.7	40	42	5.4	5.3
Dow Chemical[c]	4,485.0	743.0	13	47	16.6	12.7	20	76	15.4	10.5
Ethyl[c]	729.1	56.4	12	6	7.7	8.2	25	17	10.4	11.0
First Mississippi	118.2	8.6	87	594	7.3	2.0	22	65	8.4	6.3
H. B. Fuller	177.6	1.9	15	−59	1.1	3.1	15	−32	2.6	4.4
Georgia Gulf	317.8	55.4	43	43	17.4	17.4	49	75	18.2	15.5
B. F. Goodrich[c]	639.0	53.0	16	30	8.3	7.4	11	97	9.2	5.2
W. R. Grace[c]	1,397.2	30.3	8	9	2.2	2.1	21	15	3.3	3.5
Great Lakes Chemical	145.1	28.6	4	19	19.7	17.2	12	59	19.1	13.5
Hercules[c]	681.6	37.1	3	−7	5.5	6.0	5	−30	5.0	7.4
International Flavors	227.2	38.5	1	7	16.9	16.0	7	14	15.6	14.6
International Minerals	258.4	22.0	12	−3	8.5	9.8	−41	−12	8.0	5.3
Loctite	116.4	14.1	7	35	12.1	9.6	11	33	11.5	9.6
Lubrizol	343.1	30.7	17	29	8.9	8.1	12	24	8.3	7.5
Monsanto[c]	2,265.0	222.0	6	6	9.8	9.9	7	19	7.2	6.4
Nalco Chemical	249.5	25.1	6	1	10.1	10.6	14	22	10.5	9.8
Olin[c]	671.0	34.0	18	17	5.1	5.1	19	25	4.3	4.1
Petrolite	72.4	3.1	−9	−34	4.3	5.9	0	−29	3.9	5.5
Quantum Chemical[c]	814.1	71.4	9	−25	8.8	12.8	15	75	11.9	7.8
Rohm & Haas[c]	679.5	53.1	10	−15	7.8	10.0	13	10	8.5	8.7
Union Carbide[c]	2,241.0	201.0	15	99	9.0	5.2	20	207	9.5	3.7
Vista Chemical	198.5	32.5	−8	12	16.4	13.4	7	45	16.4	12.1
Witco[c]	399.5	17.1	1	−14	4.3	5.1	7	10	5.0	4.9
Total 15 larger firms	**$18,142.4**	**$1809.2**	**11%**	**25%**	**10.0%**	**8.8%**	**14%**	**53%**	**9.5%**	**7.1%**
Smaller 15 firms	**$ 2,853.4**	**$ 320.8**	**15%**	**10%**	**11.2%**	**11.7%**	**23%**	**41%**	**12.7%**	**11.0%**
GRAND TOTAL	**$20,995.8**	**$2130.0**	**11%**	**22%**	**10.1%**	**9.2%**	**15%**	**51%**	**10.0%**	**7.6%**

a After-tax earnings from continuing operations excluding significant nonrecurring and extraordinary items. b After-tax earnings as a percentage of sales. c One of the 15 largest companies.

working to shrink margins in the first quarter.

The cost-price squeeze has created an even bigger split between the large companies with more basic chemical business and the smaller firms, for which derivative products account for a larger share of earnings on C&EN's list of 30 major chemical companies.

Combined first-quarter earnings from continuing operations excluding significant nonrecurring and extraordinary items for the 30 companies climbed 22% to $2.13 billion from the same period last year. Composite sales of these companies increased 11% to a total of almost $21.0 billion. As a result, the aggregate profit margin (earnings as a percentage of sales) rose to 10.1% in the first quarter of this year from 9.2% in the same period in 1988.

In terms of profit growth, the larger firms on the list outperformed the smaller ones and the bigger companies closed in on the smaller firms in terms of profitability.

For the 15 larger firms, combined earnings were up 25% to $1.81 billion on a sales increase of 11% to $18.1 billion. As a result, the profit margin for the group averaged 10.0%, up considerably from the 8.8% average recorded in first-quarter 1988.

The smaller firms, although leading in sales growth, averaged much less earnings growth in the period, with combined after-tax results rising just 10% to $321 million. Sales increased 15% to $2.85 billion. But as sales rose faster than earnings, profit margins slipped to 11.2% in the first-quarter this year from 11.7% in the same period in 1988.

The effect of chemicals on earnings is evident in the first-quarter results of oil companies. For eight oil producers reporting chemical results—Amoco, Exxon, Chevron, Mobil, Occidental Petroleum, Shell, Texaco, and Unocal—combined earnings from these operations climbed 75% in the quarter to almost $1.5 billion. This figure is slightly misleading in that Occiden-

Earnings declined at many oil firms, rose at others

	FIRST-QUARTER 1989					
	Sales	Earnings[a]	Change from 1988		Profit margin[b]	
	($ millions)		Sales	Earnings	1989	1988
OIL AND GAS COMPANIES						
American Petrofina	$ 718.9	$ 48.8	19%	60%	6.8%	5.0%
Amoco	6,526.0	458.0	14	−2	7.0	8.2
Ashland	1,900.0	−5.0	0	def	def	1.1
Chevron	7,700.0	313.0	3	−29	4.1	5.9
Exxon	22,244.0	1,270.0	1	−13	5.7	6.6
Kerr-McGee	717.1	33.9	8	225	4.7	1.6
Mobil	14,024.0	429.0	1	−22	3.1	3.9
Occidental Petroleum	5,143.0	76.0	15	31	1.5	1.3
Phillips Petroleum	3,102.0	190.0	7	46	6.1	4.5
Shell Oil	5,178.0	362.0	2	2	7.0	7.0
Sun Co.	2,650.0	81.0	11	35	3.1	2.5
Texaco	9,610.0	265.0	10	−2	2.8	3.1
Unocal	2,637.0	87.0	14	98	3.3	1.9
DIVERSIFIED MANUFACTURERS						
Allied-Signal	2,942.0	126.0	0	13	4.3	3.8
Borden	1,803.9	59.0	13	13	3.3	3.3
Du Pont	8,674.0	736.0	10	25	8.5	7.5
Eastman Kodak	3,900.0	200.0	17	−23	5.1	7.8
Engelhard	587.3	14.4	15	7	2.4	2.6
FMC	837.1	30.0	17	24	3.6	3.4
Ferro	271.5	12.4	13	11	4.6	4.6
3M	3,017.0	318.0	8	15	10.5	9.9
Morton-Thiokol	708.7	0.5	17	−99	0.1	6.9
PPG Industries	1,459.0	129.8	6	9	8.9	8.6
Tyler	163.6	−2.0	7	def	def	1.9
Vulcan Materials	217.5	15.7	7	1	7.2	7.7
PHARMACEUTICAL COMPANIES						
American Home Products	1,519.8	263.8	8	11	17.4	16.8
Baxter Travenol	1,774.0	101.0	9	11	5.7	5.6
Becton Dickinson	462.9	41.6	8	15	9.0	8.4
Bristol-Myers	1,602.2	237.1	5	13	14.8	13.9
Eli Lilly	1,225.0	284.7	14	22	23.2	21.8
Merck	1,571.4	340.4	9	25	21.7	18.9
Pfizer	1,436.3	240.8	11	10	16.8	16.9
Rorer Group	241.2	9.8	10	17	4.1	3.8
Schering-Plough	831.8	125.7	11	24	15.1	13.5
SmithKline Beckman	1,241.8	130.2	7	−22	10.5	14.3
Upjohn	755.1	103.0	14	8	13.6	14.4
Warner Lambert	1,019.7	101.1	10	21	9.9	9.0

a After-tax earnings from continuing operations excluding significant nonrecurring and extraordinary items. b After-tax earnings as a percentage of sales. def = deficit.

tal's results include earnings from Cain Chemicals, acquired by Occidental after the first quarter of 1988. Even excluding Occidental, however, composite earnings for the remaining seven companies increased 65% to $1.22 billion. The 75% chemical earnings gain contrasts with an 11% total earnings decline for these eight oil companies.

For 13 oil companies surveyed by C&EN, combined first-quarter earnings fell 7% to $3.61 billion from the year-earlier quarter on sales up 5% to $82.2 billion. This resulted in a profit margin of 4.4% for the group in the first quarter compared with 5.0% in the same quarter in 1988.

In spite of the lower earnings gain than in previous quarters, the chemical industry continues to outperform other industries in terms of sales and earnings growth. It was beaten, among industry groups surveyed, only by pharmaceuticals in return on sales.

For 12 pharmaceutical companies, composite first-quarter sales increased 9% to $13.7 billion and earnings rose 13% to $1.28 billion. Profit margins for the 12 firms averaged 14.5% in the first quarter, up from 14.0% in the same period last year.

And for 12 companies classified as diversified and other, combined sales in the first quarter rose 10% to $24.6 billion and earnings increased 8% to $1.64 billion. This resulted in an average profit margin of 6.7% for the quarter, down from 6.8% last year.

Improvement in results seems to be worldwide for most companies. At Union Carbide, for instance, only Latin America showed a decline in operating profit for the quarter, and sales increased in all geographic regions. Monsanto had similar results. Dow Chemical points out that it set all-time quarterly records for sales and operating income in both the U.S. and Europe.

For the rest of the year most chemical executives see continued growth, but are tempering their forecasts with some caution. At Dow, president and chief executive officer Frank P. Popoff says, "There was continued growth in the first quarter with all indicators pointing toward a strong second quarter. While rising interest rates in the U.S. may constrain the interest-sensitive sectors of the economy, I'm confident 1989 will be another record year for Dow based on the quality of the first-quarter results and the continued strength of our global business."

And at Rohm & Haas where earnings were down 15%, chairman and chief executive officer J. Lawrence Wilson says, "In normal times Rohm & Haas reports earnings growth in strong economic environments. Thus, we are disappointed in our first-quarter results. The quarter-to-quarter comparisons should improve as the year progresses, if current economic levels are sustained. However, this may be an optimistic outlook if isolated instances of first-quarter softness become widespread in later quarters." □

Changes pushing companies toward globalization

Exploiting changing operating conditions in and between key regions and countries of the world will become more important to corporate success in the future, according to two speakers at the recent Chemical Marketing Research Association meeting in New York City.

"Within and between North America, Europe, and the Pacific Rim, the new global operating environment is pushing countries toward greater economic integration," says Frank R. Wyant, chief economist of Air Products & Chemicals. To survive, "chemical companies will have to operate within as well as between" these primary economic regions, he told the meeting.

And according to Koji Yoshida, assistant general manager of Mitsui Toatsu Chemical's U.S. office in New York City, "Globalization might be a necessity for the Japanese chemical industry" in order to survive globalization efforts by U.S. and European chemical giants. Mergers and acquisitions, he says, "might be one of the best ways" for Japanese chemical manufacturers to achieve both growth and globalization.

Most of the world's new information, knowledge, and technology will emanate from the primary spheres of North America, Western Europe, and Japan, Wyant says. Since most of the world's new products and processes will be developed in one of these three core areas over the next decade, "manufacturing competitiveness will depend increasingly on a corporation's ability to operate in all three primary manufacturing spheres."

The secondary industrial spheres—Latin America, the Pacific Rim, Africa, the U.S.S.R., Eastern Europe, and China—will depend "on the research, development, and commercialization of processes and products that take place in the primary spheres," Wyant says. Additionally, since the secondary spheres "do not offer world-scale markets, successful manufacturing operations in these areas will depend, directly or indirectly, upon international trade."

Wyant believes that as a result of international and industrial realignment, basic manufacturing industries such as steel, shipbuilding, and construction will shrink in North America, Western Europe, and Japan, as the newly industrialized countries' share of these industries grows. Newly industrialized countries also will provide competition, particularly in computers, electronics, and biotechnology. But over the next decade he believes that the great bulk of world manufacturing will remain concentrated in North America, Western Europe, and Japan.

North America will slightly lead Western Europe and Japan in the decade ahead, Wyant predicts. The 1979 and 1982 recessions as well as the dollar appreciations from 1983 to 1985 forced quality and efficiency improvements by North American manufacturers. They will be able to reap the benefit of these improvements in the decade ahead. And he thinks they also will benefit from "reasonably valued currencies and by liberalized trade."

As industrial growth surges in the next decade, Wyant believes that "significant chemical market industry growth will take place in the auto, chemical, and electrical machinery industries." Extrapolating from statistics compiled from the United Nations Industrial Statistics Yearbook, Wyant predicts that North America will lead the chemicals and paper industries, the Pacific Rim will lead in electrical machinery and textiles, and that North America and the Pacific Rim will become equals in the automotive industry.

As for the chemical industry, North America, Europe, and the Pacific Rim accounted for 36%, 32% and 25%, respectively, of world chemical output, says Wyant. By 1998, he predicts, Europe will lose share to North America and the Pacific Rim. Then North America will contribute 39%, Europe 28%, and the Pacific Rim 28% of global chemical output.

Japan's chemical industry is not so highly developed or diversified as is the chemical industry in either Western Europe or the U.S., says Yoshida. Average sales of the five largest chemical companies in Japan were $3.3 billion in 1987, compared with $8.5 billion for the five largest U.S. producers and $18.5 billion for the five largest Western European chemical companies. And although the U.S. and Europe have a chemical trade surplus, Japan has a slight deficit, he says.

Yoshida says that Japanese chemical companies have traditionally been domestically oriented. Japan's export ratio has been less than 10% of production, whereas the U.S. and Europe traditionally have exported a much greater portion of their production.

R&D expenditures for five large Japanese chemical companies averaged $169 million in 1987, about one fourth of the average for five large U.S. chemical firms and one fifth of the largest European chemical firms, Yoshida says. However, the Japanese chemical industry has been increasing its R&D expenditures 10% annually. U.S. chemical company R&D expenditures have been growing at about the same rate (C&EN, June 20, 1988, page 55).

Japanese chemical companies might have to globalize their oper-

Europe's chemical giants dwarf biggest U.S., Japanese firms

$ Billions	1987 sales
EUROPE	
BASF	$22.40
Bayer	20.60
Hoechst	20.60
ICI	18.40
Ciba-Geigy	10.60
TOTAL	**$92.60**
AVERAGE	**$18.52**

$ Billions	1987 sales
U.S.	
Du Pont	$13.10
Dow Chemical	10.80
Exxon	7.18
Union Carbide	6.18
Monsanto	5.16
TOTAL	**$42.42**
AVERAGE	**$ 8.48**

$ Billions	1987 sales
JAPAN	
Mitsubi Kasei	$ 4.50
Sumitomo Chemicals	3.73
Showa Denko	3.00
Ube	2.64
Mitsui Toatsu	2.63
TOTAL	**$16.50**
AVERAGE	**$ 3.30**

Source: Mitsui Toatsu Chemicals

ations as a "last chance" for survival, Yoshida says. Globalization is the only way to compensate the industry "by selling a newly developed product to a global market."

By targeting U.S. chemical companies for mergers and acquisitions, Japanese chemical companies hope "to meet the challenge of American chemical giants," says Yoshida. He believes that Japanese investment in the U.S. chemical industry will foster improved productivity and competitiveness for the U.S. chemical industry as a whole.

Marc Reisch

Steel processor eyes waste treating business

Often a problem can lead to a new business opportunity. A case in point is Meridian National Corp., a steel processor that had to dispose of a sulfuric acid waste stream.

Meridian National is a Toledo, Ohio-based distributor and processor of steel, primarily for the automotive and appliance businesses. Its pickling and steel oiling operations in the Midwest smokestack corridor generate a considerable volume of waste sulfuric acid. As the company has learned how to recycle that waste stream economically, its executives have chartered an expansion course with the aim of profitably treating and recycling metal-contaminated acid wastes generated by other smokestack businesses.

Between 1982 and 1985, the cost of disposing of sulfuric acid waste rose from 6 cents per gal to 42 cents per gal, says William D. Feniger, chairman and chief executive officer of Meridian National. The company found that it could recycle the sulfuric acid, which it uses to clean scale from the steel it processes. The ferrous sulfate heptahydrate removed in the regeneration process could then be sold to magnetic tape manufacturers such as 3M, and animal feed manufacturers such as Purina, as well as to fertilizer, vitamin, and paint pigment producers.

An initial capital investment of some $700,000 allowed Meridian National to start up an acid regeneration facility operating as a separate subsidiary, National Chemical Services, in 1987. By recycling the sulfuric acid generated at its two pickling facilities, the company was able to save $500,000 yearly through its subsidiary, says Feniger. The recycling effort turned out so well, Meridian National decided to take a look at the acid waste streams generated by other companies in the area. In addition to sulfuric acid, there are hydrochloric and chromic acid as well as zinc waste—all generated in the metal treatment business with which the company is familiar.

Meridian National thought it might "go after other people's acids," and learned that "15% of the acids in our area can be economically regenerated," says Feniger. But there was a hitch. Potential customers "didn't want their recycled wastes back. They just wanted them to go away." And along with the regenerated acids that producers did not want back, there was the 85% of liquid waste streams from the auto and steel industry that could not be regenerated and still had to be disposed of.

These acid wastes, however, do not just go away, points out Feniger. Pressure from the Environmental Protection Agency as well as pending federal and state legislation are beginning to limit disposal options for acid waste streams. EPA will eliminate the disposal of acid waste streams, of the type Meridian National is prepared to process, from deep-well injection by 1990, he says. And interest is growing within federal and state legislatures to ban the interstate shipment of hazardous waste, he adds.

Another option for acid waste disposal, via wastewater treatment facilities, appears to be on the way out, says Feniger. Much of the iron-contaminated acid waste stream from the steel processing industry in the Midwest goes to local municipal wastewater treatment facilities where the waste acid is used to treat alkaline effluent. Many of the metal-contaminated municipal waste streams drain into Lake Erie, a source of drinking water for the communities on the lakeshore. "It's a joke. This can't go on," says Feniger.

The limitations soon to be placed on acid waste disposal will provide a niche for Meridian National's National Chemical Services. After three years and an expenditure of some $1.3 million, Meridian National received a final EPA-approved permit last September to build a facility in Detroit large enough to treat liquid acid wastes it can collect from nearby generators such as Great Lakes Steel and Rouge Steel. The Detroit area alone generates about 300,000 gal of liquid hazardous waste daily.

Meridian National plans to recover not only ferrous sulfate heptahydrate from spent sulfuric acid, but also ferrous chloride from hydrochloric acid, and other marketable raw materials from other acid wastes it processes. Whatever acids cannot be recycled for sale will be filtered and the clarified liquid will be neutralized and can be flushed into the sewer system, says Feniger. The filtered solids, he says, can be buried in a nonhazardous waste landfill.

The National Chemical Services facility currently can handle 40,000 gal of waste daily; $6 million of a recent $7.5 million public offering of stock and warrants in Meridian National will finance a boost in capacity at the facility to 72,000 gal per day. Feniger says capacity at the Detroit facility will be easily expandable to 144,000 gal.

At its maximum capacity, the liquid waste treatment facility could be producing annual revenues of $20 million to $25 million "and be very profitable," according to Feniger.

Profits from National Chemical Services as well as the company's recent initiatives into solid waste landfill management and environmental consulting might help provide a less volatile performance for the steel services company. Meridian National's revenues for the fiscal year ending Feb. 28 were $57 million, up 90% from the comparable period in 1988. However, net profit, $252,000, was down 48%.

Meridian National has no intention of abandoning the steel services business. Its steel distribution, oiling, and pickling operations will "continue to grow and will be the building block for the company," Feniger says.

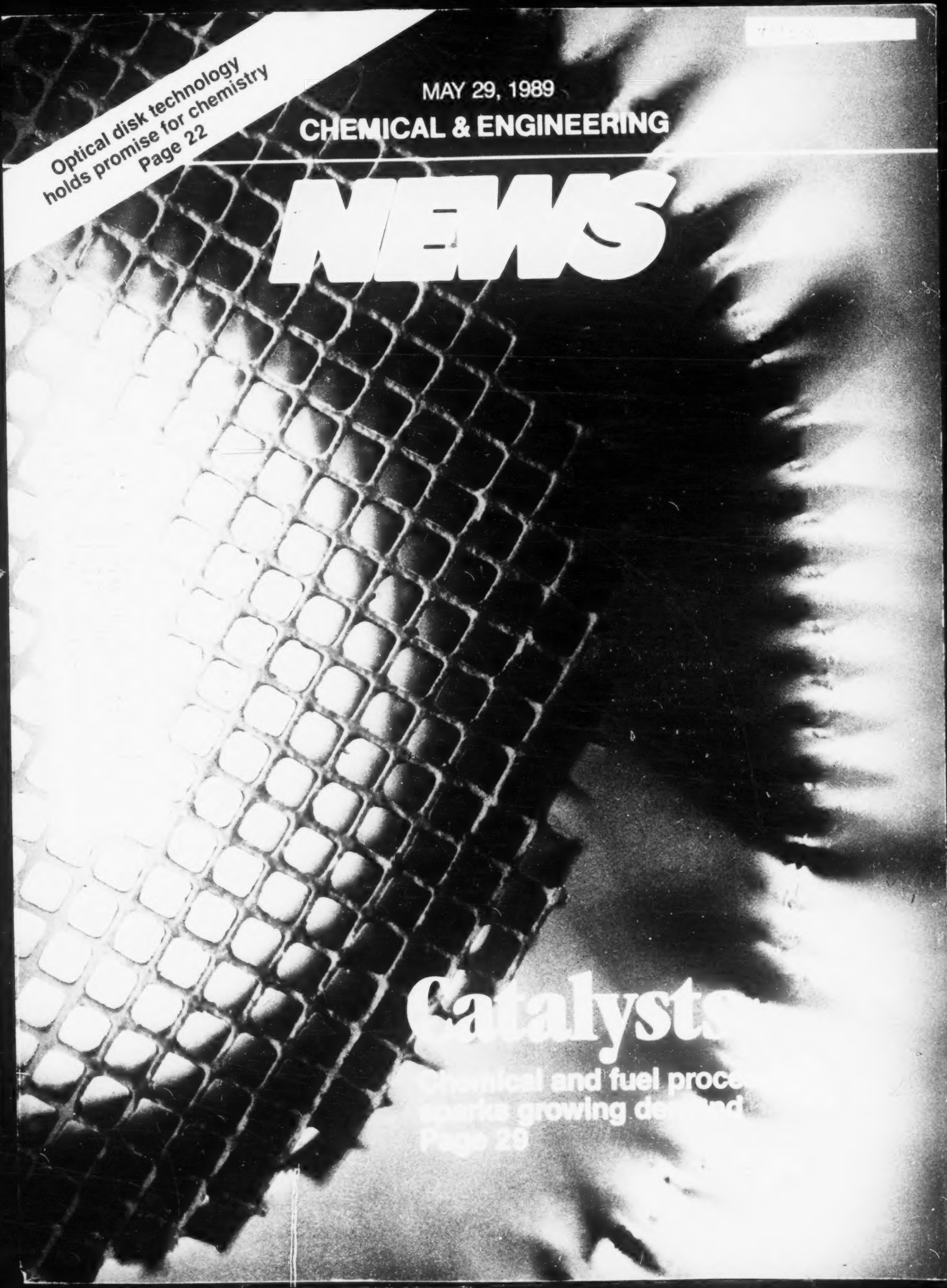
Marc Reisch

MAY 29, 1989

CHEMICAL & ENGINEERING

NEWS

Optical disk technology
holds promise for chemistry
Page 22



Catalysts

Chemical and fuel proce
sparks growing demand
Page 29

CHEMICAL & ENGINEERING
NEWS

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MAY 29, 1989

News of the Week

- **Industry and government efforts to deal with Alaska oil spill called slow, inadequate, and confused in report to President Bush.** **Page 4**
- **Scientists at National Institutes of Health carry out first test using genetically altered cells in a human patient.** **Page 5**
- **Higher pay for patent, FDA examiners urged by the Pharmaceutical Manufacturers Association.** **Page 5**
- **Representatives of chemical industry air views on chemical weapons issues.** **Page 6**
- **Du Pont will purchase Howson-Algraphy, Britain's largest lithography plate firm, for $400 million.** **Page 6**

Cover: Engelhard honeycomb catalytic system designed for automotive engines

Letters 2

Concentrates
Business 7
Government 16
Science/Technology 21

The Departments
Software/Database Update 28
New Products 46
People 61
Newscripts 76

Business

PPG is expanding overseas, adding noncyclical products in ongoing program to buffer effects of U.S. business cycle; Shell tightens in on expansion plans for Far East; data show correlation between capacity use and inflation. **Page 9**

Insights

Du Pont chief Edgar S. Woolard Jr. sees need for chemical companies to develop an environmental stewardship in line with public desires and expectations. **Page 12**

Government

Review of Superfund will call for revamping its implementation, though former head of program believes no major changes are needed. **Page 17**

Science/Technology

Advances in optical disc technology and an expansion of the topics available on disc provide for a range of science, education uses; series of organotitanium reagents facilitate aldehyde additions; new exchange resin developed for plutonium recovery. **Page 22**

ACS News

A French-designed multimedia exhibit about chemistry acquired recently by the society will tour major science museums across the U.S. and Canada beginning next month. **Page 58**

Product Report

Catalysts find growing use in making chemicals and polymers, fuels from petroleum, products that reduce pollution, and biological materials. **Page 29**

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LETTERS

Patent protection

SIR: This is in regard to your article, "Foreigners Win Almost Half of 1988 U.S. Patents" (C&EN, March 27, page 5). Counting the number of patents granted to foreigners in a given time period is a simple exercise. It is much more difficult to determine how much patent protection was awarded to applicants from different countries.

In the U.S., the first inventor gets the patent. In most other countries, patents are awarded to the first inventor to reach the patent office. In the U.S., we also have the benefit of a one-year grace period, which allows inventors to "swear behind" publications that appear prior to the filing of a patent application. This advantage is available in only one or two other countries. In most of the world, publication—no matter how briefly before filing—can cause a loss of patent rights.

These differences encourage U.S. inventors to take more time to perfect and broaden their inventions. The laws of other countries promote racing to reach the patent office as early as possible.

There is probably no practical way to compare the breadth of protection awarded to U.S. inventors as opposed to foreign inventors, but I suggest that U.S. inventors are perhaps not losing so much share in terms of real patent protection as the naked numbers of patents granted might seem to indicate. All patents are not equal!

R. C. Brown
Managing Patent Counsel
Union Carbide Corp.

Safety data sheets

SIR: I would like to comment on the letter from Mona F. Zady (C&EN, March 20, page 4) regarding material safety data sheets. I am the regulatory and technical coordinator for a major chemical company in California. In addition to all the federal Occupational Safety & Health Administration and Superfund regulations, we must contend with California's own OSHA, and the mammoth Safe Drinking Water & Toxic Enforcement Act of 1986 (known as Proposition 65). Our responsibility to our customers is tremendous, to the point where we employ a staff for management of our material safety data sheets.

In principle, I wholeheartedly agree with Zady's point that companies are exaggerating the potential hazards of some chemicals. I, personally, have been astounded when reviewing the toxicity information for "harmless" compounds such as sodium chloride, lactose, and potassium bicarbonate. I particularly agree with her point regarding the likelihood of user apathy developing when material safety data sheet warnings become out of hand, as in her sucrose citation. The real problem for me, however, is just the opposite: trying to effectively relay the legitimate hazards of chemicals worthy of concern. Although I am considerate of the liabilities potentially arising for my company should the required information fail to be included with hazardous items, I am much more worried about the casual and neophyte user (not to mention those for whom English is a second language!) who fails to take the time to read our data sheets or fails to adhere to the safety guidelines included therein.

Owing in large parts to the influence of Proposition 65 regarding carcinogenic chemicals, I would very much like to see the American National Standards Institute ratify a universally recognized symbol for carcinogens, as they have for flammable, corrosive, explosive, and toxic compounds. Many carcinogens are also suspect teratogens, making their impact not only immediate, but potentially present for generations. If asbestos set the tone for carcinogens of industrial concern, the list grows ever longer, and will only continue to do so as our empirical data accumulate.

Obviously, the safety gear recounted by Zady for handling sucrose is preposterous. But it is extremely important that the users of chemicals pay mindful attention to all warnings (on the label of the containers as well as on the data sheets). So many compounds have little or no toxicity data compiled on them, and for scores of others the information is outdated when you consider modern toxicological methods. When strident warnings are included, most of the time, they are there for a reason and are not discountable. The chemical industry mustn't allow its members to become cavalier about the inherent dangers of the field. The more we learn about chemical toxicology, the more overwhelming and frightening it becomes, Zady's observations notwithstanding.

Diana Hale Wilson
Gardena, Calif.

SIR: In her letter, Mona Zady commented on the safety equipment recommended in material safety data sheets for cleaning up spills of table sugar.

I think it should be pointed out that material safety data sheets are legal documents. Those of us who write, edit, and

Review To Call for Revamp of Superfund's Implementation

Despite heavy criticism from Congressional, environmental sources, former program head claims that there's no need for major changes

Lois R. Ember, C&EN Washington

Superfund was born in the turmoil of fear, and eight years later it is still embroiled in the flames of controversy. Not surprising for a difficult, costly, and complex program operating within a partisan, political framework.

Superfund, aimed at cleaning up abandoned hazardous waste sites, was conceived in the Carter Administration, which was generally supportive of environmental issues. But the bulk of its implementation fell to the Reagan Administration, which, according to one House aide, "was hostile to the whole program." The Reagan White House saw Superfund as a five-year program, and fought to ensure there would be no "son of Superfund."

That there will be a need for many sons of Superfund is now conceded by nearly everybody, including the former head of the program, J. Winston Porter. Porter also believes that the program, as he administered it, is on target.

However, many Congressional sources say the Bush Administration, recognizing that Superfund is in trouble, has undertaken a review to get the program back on track. The review is slated to be completed this week, on May 31, but that date is likely to slip to June 6.

The Reagan Administration's antagonism to Superfund led to a "bit of a bunker mentality," according to one critic, and the predictable results occurred. In the past two years more than a dozen reports have been published sharply critical of one or another aspect of the program. If there is a common theme to all the studies it is this: Superfund as reauthorized in 1986 is fine; its implementation is flawed, however.

C&EN staff photos

Porter: got program to high level

Critics charge that the wellspring for this failed management was a lack of leadership at the political level at EPA. Says Sierra Club's Washington, D.C., representative A. Blakeman Early, the absence of leadership led to "many of the requirements in the law not being observed. EPA spent much of its time trying to get around the law, or interpreted the law at the margins of credibility."

Porter, who as a political appointee ran the program for three and a half years before he was asked to leave this March, disagrees. He believes that "The biggest problem with Superfund is the criticism that it is not working."

As he relates it, "EPA was usually on the defensive, always reacting to criticisms from Capitol Hill." There's a need for oversight, for independent review, Porter says, "especially for [a program] this big, expensive, and complicated, but I think it may have been overdone."

Given a second opportunity, Porter says, "I think I'd spend even more time and I would have my people spend more time explaining the program. We tried, but we were not very effective."

Many of the people contacted by C&EN lay the program's quagmire directly at Porter's feet, not just for his lack of communication but for what he communicated and for his method of implementing Superfund. These sources are quick to say that they believe Porter is a decent man who was doing what he thought best and what he thought the Administration wanted. But they strongly contend that he implemented the law as he interpreted it, not as Congress mandated it.

Porter conveyed the message that "he knew better than Congress how to clean up Superfund sites because he is an engineer and members of Congress are lawyers," a Senate staffer says. "After seeing him at many hearings I came away with the view that he knew how to do it, that he was the engineer, that he was smarter than others," says Sierra Club's Early. "His message: Let the experts make the decisions."

Porter is knowledgeable. He obtained a Ph.D. degree in chemical engineering from the University of California, Berkeley, and he is a registered professional engineer in California, Texas, and Virginia. He was chosen to run the Superfund program after Lee M. Thomas was elevated to EPA Administrator because Superfund is primarily an engineering and construction-centered law.

Former EPA official grades Superfund

J. Winston Porter was Environmental Protection Agency assistant administrator for Superfund in the final three and a half years of the second Reagan Administration. He divides Superfund into four parts and grades EPA's performance in each.

Screening: EPA has about 30,000 potential Superfund sites in its inventory. EPA and the states have done preliminary assessments at 27,000 of these sites. About 1200 sites at this point are actual Superfund sites. This whittling-down process is very valuable, and EPA and the states are doing about 2500 preliminary assessments a year. I give this part of the program at least an A−.

Emergency removal: This program corrects problems like leaking tanks. EPA spends about $100 million a year on this part. Close to 300 of these are done a year between EPA and responsible private parties. About 1800 have been done since the program started in 1981. This part of the program has functioned very well. I'd give it a solid A.

Enforcement and settlement: EPA and the Department of Justice have had about 500 settlements, meaning we reached agreement with potential responsible parties to either do an emergency removal or a long-term remedial cleanup. We've recovered over $1 billion, either in money recovered or agreements to do work. This part of the program is more complicated than the first two, but it has been improving. I'd give it a B or B+.

Remedial cleanups: This is the part of the program by which EPA and the states with their own contractors are doing the cleanup, paying for it out of Superfund money. This part of the program has the most room for improvement. I would give it about a C+ or B−, not because EPA is not working hard and not because it doesn't care. These are very tough problems technically. Many different views have to be considered. Every problem is different—no two sites are the same. Operating within the bureaucracy of the federal government is not easy.

But Superfund also operates in a political arena, demanding that the person who runs the program be a skilled diplomat and negotiator.

At EPA Porter says he worked very hard at "getting [staff] to think like project managers, engineers, and construction people," a task made difficult because EPA is "not an implementing agency." And he struggled to get responsible private parties not only to pay for cleanups but also to actually do them. "Three years ago, about 20% of the work was being done by responsible parties," he says. "When I left, about 50% of the work was being done by them."

Given the enormity of the cleanup task and the relatively limited funds available to carry it out, Porter's bent was to contain contamination at a lot of sites. Containment techniques are generally less costly and quicker to carry out than such permanent treatments as incineration. A Senate aide says Porter "tried very hard to nip permanent treatment in the bud. It is known that he went to Thomas and complained that one EPA regional office was using incineration too often. He believes that incineration is too expensive. I was told by high-level staff at EPA that this sent a chill throughout the program."

Porter tells C&EN that "The emphasis on treatment and its being equated to permanency is troublesome to me. I want a good remedy and that may not be treatment." Porter's way of addressing hazardous waste cleanup may be more correct from an engineering and economic point of view. But Congress said that its preference is to use permanent remedies and that it wants to attack as many sites as possible through permanent treatment.

This yawning chasm between Porter's implementation and Congress' mandate occurred because a fundamental issue has yet to be addressed by Congress, EPA, the states, and environmental groups, explains Gene A. Lucero, a partner in the Washington law firm Sidley & Austin and formerly director of EPA's Office of Waste Programs Enforcement. With only $8.1 billion to spend over five years and with cleanups averaging much more than $500,000 per site, choices have to be made.

"Is it better to deal with 1000 sites preliminarily [but with removal of the health risk] or should EPA really focus on permanent remedies at a few sites?" Lucero asks. Until this basic dialogue takes place and a choice is made, not much can be achieved, he believes.

EPA and especially the assistant administrator responsible for the Superfund program "have to take the lead in instigating the dialogue, in building a consensus. Porter didn't take it on. He is a very good engineer, but he wasn't a politician and he wasn't a policy person," Lucero says.

Porter believes that he "made a lot of tough decisions and got the program running at a high level." He also believes that he took a lot of unjustifiable heat, especially from the Congressional Office of Technology Assessment.

OTA and others have criticized the program for being too decentralized, "with no line of authority to headquarters." This has led, they say, to a situation in which there is no national consistency in the selection of cleanup remedies.

"A particular regional administrator may not come up with exactly the same remedy that another one has, given the same facts," Porter says. "Superfund is not an exact science. But probably more relevant is that the problems were not the same."

However, a Senate staffer argues that "Many things can be replicated at different sites. There are certain generic ways to proceed." Perhaps another dialogue is warranted given these different views of centralized versus decentralized management, and generic versus unique cleanup remedies.

Porter makes a case for his management by delegation, especially to regional EPA administrators. He contends that it has led to more site cleanups. In the first six years of the program, six sites were cleaned up permanently. During Porter's reign another 44 sites were added to this list. This jump seems impressive until one realizes that EPA has more than 1000 Superfund sites to deal with.

Still there was improvement, not only in cleanups but also in the number of settlements with so-called responsible parties. "There were 85 settlements for remedial work in the first six or seven years of the program, and 55 in the past fiscal year," Porter notes. He attributes this increase to his delegation of responsibility, to his insistence that settlement negotiations end by a certain date, and to his aggressive use of "mixed funding." He calls mixed funding "a powerful tool" whereby EPA, the states, and responsible parties pay a portion of the cleanup.

Porter has a slew of numbers to back up his claims. The only problem is that Superfund generates a morass of numbers, and current EPA figures don't always agree with Porter's count. Also, says one critic, Superfund managers were "only interested in bean counting, which subtly undermined the program because the various EPA regional offices needed to meet targets without regard to quality."

This is not to say that Porter didn't redouble his efforts to ensure that good remedies were chosen. But, again the root of the criticism may be traceable to poor communications. As Porter explains, "We are all throwing around these numbers and often we are talking apples and oranges. One of the things I worked on very hard—but there is still plenty of room for improvement—is to do a better job explaining all these numbers."

EPA uses nine criteria for selecting cleanup remedies

The following criteria are listed in the proposed National Contingency Plan, Superfund's master plan, but are not legally binding. They are, however, being used by EPA staff.

Protection of human health and the environment

Compliance with all applicable local, state, and federal requirements

Long-term effectiveness and permanence

Reduction of toxicity, mobility, or volume

Short-term effectiveness

Implementability

Cost

State acceptance

Community reaction

Not all criticism lobbed at the program or at Porter's administration of it was unhelpful. Indeed Porter found Sen. Frank R. Lautenberg (D.-N.J.), who chairs the Senate Superfund, Ocean & Water Protection Subcommittee, quite constructive, especially his emphasis on meeting schedules. "Another constructive criticism from Sen. Lautenberg's subcommittee had to do with the turnover of young staff. We were very much aware of that, but some interesting ideas came out of some of the hearings," Porter says.

The staff turnover issue crops up in many studies of Superfund, the latest being Lautenberg's subcommittee report released just a few weeks ago. This report notes that Superfund staff turnover rates exceed those for other EPA programs and for the rest of the federal government as well. This results in a young, inexperienced staff with management responsibilities for a technically complex program.

Porter has noted correctly that some of the criticisms of the program are mutually exclusive. Superfund has been criticized for its inexperienced staff. But the program also has been criticized for using too many outside contractors in lieu of staff.

According to Porter, part of the turnover problem may have been solved by getting more responsible parties to do the actual cleanup work. These parties "are big companies that know how to run big projects, which takes care of the problem I had with the turnover among the young people," Porter explains.

But EPA staff still has to manage emergency cleanups and those long-term cleanups for which responsible parties cannot be found or where the parties refuse to do the cleanups. There is no question that with Superfund "EPA was given a Herculean task, made more difficult by the agency not being able to get the best people or keep a trained work force," Lucero says.

Superfund scoreboard

Number of Superfund sites	1,173
Potential Superfund sites	30,844
Number of emergency cleanups	1,837
Number of sites cleaned up	50
Number of Superfund sites deleted from the National Priority List	26
Remedial investigation (RI)/feasibility studies (FS) under way	681
Record of decisions (or RI/FS completed)	438
Remedial action at Superfund sites	
Under way	174
Completed (at portions of sites)	103
Total Superfund money authorized by law	$10.1 billion
Amount spent to date	$4.5 billion
Number of judicial settlements	101
Amount of settlement recoveries	$128 million
Total of cost recovery action initiated at 273 sites	$343 million
Enforcement actions	702
Amount of enforcement actions	$2.21 billion
Administrative orders to responsible parties	660

This leads Lucero to frame another of his fundamental issues. "What can EPA do to work around this institutional fact of life? Are internal review teams the answer?" Lucero asks. He doesn't answer these questions, merely offers them as the basis for dialogue.

As much as Porter applauds Sen. Lautenberg, he damns OTA. "The only group I felt was consistently unfair was OTA, and specially Joel S. Hirschhorn," who authored OTA Superfund studies, Porter says. He accuses Hirschhorn of gross oversimplification by extrapolating from a few sites to the whole program. He faults OTA reports for not being peer reviewed, and for containing factual errors. He says Hirschhorn carried out "over-the-telephone engineering. And since he is not a design or project or construction engineer he tends to oversimplify things."

Hirschhorn says, "Every report we put out has to go through external review, sometimes twice." As for the charge of over-the-telephone engineering, he responds, "I do a detailed analysis based on getting information from many different sources inside and outside the government." As to the charge of errors, Hirschhorn answers, "There is not one case in which EPA has ever documented a mistake made in OTA reports."

Porter was particularly unhappy with OTA's review of EPA's remedy selections for site cleanups. He says OTA considered only permanence and treatment, not all of the nine criteria he instructed his regional administrators to use. The criteria Porter refers to are not part of Superfund's master plan, the current National Contingency Plan, and, therefore have no force of law. But they are included in EPA's proposed NCP, which has not yet been sent to Congress as required by the reauthorized 1986 Superfund law.

Though Porter lays much importance on these criteria, others have faulted them. Early says, "They have allowed too much discretion to decisionmakers, which isn't justified by the 1986 Superfund revisions." A Senate aide says, "The legacy Porter temporarily leaves is a selection of remedy process that uses nine meaningless criteria. This is the core of the problem. There are no rules of the game because the nine criteria have no meaning. This leads to inconsistency within and across regions."

Porter sees "no need for major changes in the program's fundamentals—in remedies selected, or the way contracting is done—over the next couple of years. The framework is good; there is only need for improvement around the edges." The new administration at EPA appears to be rewriting the rules of the Superfund game, however.

EPA has undertaken a three-month review of the program, soon to be released to the public. As part of this review, Lewis S. W. Crampton, special assistant to the EPA Administrator, has been reading every criticism of the program ever written, including OTA's. "The OTA reports have been very valuable in putting together this Superfund management review. Sometimes the rhetoric has pinched a bit, but Hirschhorn hasn't lied or stretched the truth," he says.

Hirschhorn: studies well documented

This review will lay out Administrator Reilly's "management philosophy and vision for operating this program," Crampton explains. "There will be a bias toward strong enforcement, greater citizen participation in the program, and more permanent remedy selections. The review will resolve many contradictions: whether to do pristine cleanups, whether it will be a centralized or decentralized program," he adds.

"The core of our approach to implementing Superfund will be to take early action using emergency removal authority. Then to follow this with a series of corrective actions so that the site meets public health standards," Crampton says. In what he calls an "enforcement-lead process," he expects more responsible parties to do the cleanup but with better quality review from EPA.

EPA needs to declare publicly that Superfund is a long-term project, requiring another "one or two reauthorization cycles before the job is done. The agency must stop trying to achieve speed for speed's sake. It must try to inject more efficiency and quality into the program," Crampton says. Most important, the agency and Congress must enter into a dialogue so that there are "mutual expectations for the program," he says.

The fervent hope is that EPA's management review will clearly delineate a better way to implement Superfund with quality and efficiency and thereby lay to rest past criticisms. □

Clean Sites offers recommendations for Superfund upgrade

Clean Sites Inc., a private, nonprofit organization whose aim is to solve the U.S.'s hazardous waste problem, has termed the current Superfund program viable—but the Environmental Protection Agency must mend its ways. Specifically, EPA must change the way it implements the program.

With that in mind, Clean Sites offers EPA several recommendations, which former director of Superfund enforcement Gene A. Lucero finds commendable. "If a number of the suggestions are implemented, the program would run 20 to 30% better. Add an effective, politically connected person and it will run 50% better." Clean Sites' recommendations are:

- Increase responsible-party cleanups by maximizing enforcement and settlement, including an accelerated implementation of a strategic enforcement program, and pursue vigorously a limited number of "good" cases rather than merely generating more cases.
- Improve the remedy selection process by a commitment to early site action through expanded use of removal actions at Superfund sites. Where there is significant uncertainty about the remedies being considered, EPA should require an appropriate array of treatability studies to be part of the remedial investigation/feasibility study process.
- Manage the program for optimal progress by delegating site-specific decision-making authority to the regions. The position of Superfund remedial project manager should be upgraded. To avoid further delay, headquarters and regional Superfund offices should not be reorganized now.
- Define new measures of program success. New tracking measures should include the speed with which EPA is cleaning up sites, the quality of the cleanups, and the number of cleanups financed by responsible parties. EPA should provide the public with information that is readily available and clearly understandable.

PRODUCT REPORT

Process Catalysts Enjoy Surging Market

Bruce F. Greek, C&EN Houston

Screening pelletized auto emission catalysts at Degussa's Calvert City, Ky., plant

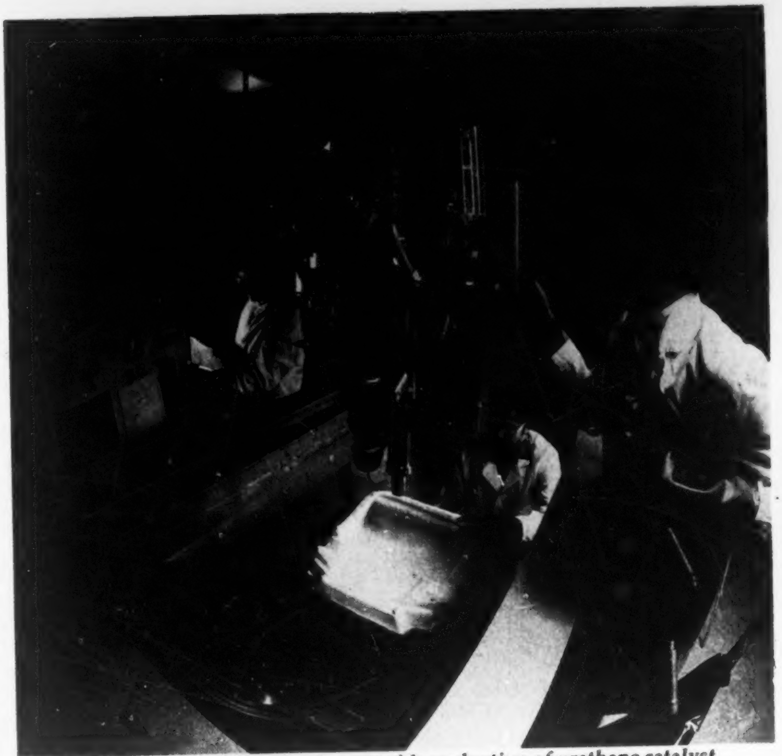
Nearly every segment of the catalyst business is growing. Strong demand for chemicals and polymers, for fuels from petroleum, for products that reduce pollution, and for biological materials is increasing consumption of catalysts. Resurging markets for catalysts also are providing new incentives for research and development in catalysts and in processes that require their use.

The worldwide market for catalysts this year likely will be valued at more than $5 billion. Most of them will be used in three major industries: chemical processing, petroleum refining, and pollution control.

From 35 to 40% of catalysts sold worldwide this year will be used in the U.S., amounting to about $1.9 billion worth. For the first time, the value of catalysts consumed in pollution abatement uses is expected to exceed the value of catalysts consumed in petroleum processing. Dollarwise, that means sales of pollution abatement catalysts will total about $650 million, petroleum refining catalysts just a little less, and chemical processing catalysts about $575 million, according to a study of catalysts by consulting firm Freedonia Group, of Cleveland.

In Western Europe, about $900 million worth of catalysts will be used this year in chemical processing, crude oil refining, and auto emission control, according to estimates in a just-completed study by Frost & Sullivan, a New York City consulting firm. For these three categories, catalysts used in Western Europe will nearly double in value by 1993, to nearly $1.8 billion, the firm forecasts. For 1989, the market breakdown for Western Europe will be about $425 million for chemical processing catalysts, $210 million for refining catalysts, and $550 million for emission control catalysts.

Nevertheless, in terms of physical volume, catalyst consumption in the U.S. and Western Europe continues to be dominated by petroleum refining. Refining catalysts account for more than 90% of the total catalyst volume because of large quantities of sulfuric and hydrofluoric acids used in alkylation processes. The physical volume of catalysts used in pollution control, ex-



At Air Products, pilot foam equipment aids evaluation of urethane catalyst for automotive application

cluding carriers for the active catalysts, is extremely small (less than 0.003% of total volume) because of high activity and cost of platinum and other metals of the platinum group used as the active catalysts.

The platinum group metals—platinum, palladium, rhodium, and ruthenium—will account for about 40% of the value of catalysts consumed in the U.S. this year. A small amount of silver used alone or as derivatives will slightly increase the share of noble metal catalysts. Nearly all platinum group metal catalysts are used for pollution abatement, and nearly all of that, 95%, is for catalytic devices in automotive exhaust systems.

Longer term, pollution control (largely using platinum group metals as the active catalysts) will take an increasing share of the value of catalyst materials. Behind their increasing value, and increasing prices, will be greater demand driven by worldwide efforts to reduce air pollution and, to a lesser extent, by increasing use of these metal catalysts in the chemical and refining industries. By 1992, for example, pollution control will account for 40 to 45% of the value of catalysts sold in the U.S., and this share will rise to more than 50% by the year 2000, according to the Freedonia Group study. Demand for industrial pollution control using catalytic processes is growing faster than motor vehicle pollution control, but the industrial segment is growing from a base that is 5% of the volume used in motor vehicles.

Physical volume of platinum group metals consumed as catalysts for all uses is forecast by Freedonia Group to increase an average of 5.1% annually through 1992, using 1987 as the base year. The value of of these metals will increase 14% annually during this period. Physical volume growth for most other catalyst materials will average 1.4% annually because the share of the commodity chemicals is relatively large. Value growth for other materials, excluding the commodity chemicals and platinum group metals, will be in the 2 to 3% range, except for peroxides, which will average 6.7% for the 1987–92 period.

Total consumption of platinum group metals for all uses in the U.S. peaked in 1985 at more than 2.27 million troy oz, according to the Department of the Interior's Bureau of Mines. By 1987, the latest year of available data, consumption had declined to 1.94 million troy oz. In addition to automotive emission catalysts, these metals have applications in, among others, chemical processing, crude oil refining, electrical components, jewelry, and dentistry. U.S. imports of platinum group metals have been holding at about 4 million troy oz, and exports of the metals have declined to about 700,000 troy oz, from 1.3 million in 1983.

Automotive catalysts accounted for 43% of all U.S. consumption of these metals in 1987, according to Bureau of Mines figures—including 73% of both platinum and rhodium. Chemical processing required 5.3% of platinum group metal consumption that year, and petroleum refining only 3.2%. Other uses, such as electrical components, jewelry, and dentistry took the remaining share of about 47% of the total. Because these metals have few competitors in automotive uses and in uses other than chemical and refining, prospects for their consumption seem unlikely to depend on supply and selling prices, unless prices rise greatly or imports are cut off.

Other commercially significant materials used as catalysts (other than the noble metals) include various base metals (alone or as their oxides), zeolites (complex aluminosilicates), peroxides (not technically catalysts but free radical initiators), the commodity chemicals, and miscellaneous others, including rare-earth elements.

In addition to active catalytic agents, large quantities of carriers are used in preparing catalysts for use. Some of the carriers—aluminum oxide, for example—also provide catalytic activity and, with another catalytic material, may be considered to be components of a bifunctional catalyst. Other carriers are clays, many kinds of minerals (such as silicas and aluminas), and zeolites. The difference between zeolite carriers (or supports) and zeolite catalysts often depends on physical properties of these materials. Developing carriers and supports for catalysts is becoming as much a science as is catalyst development.

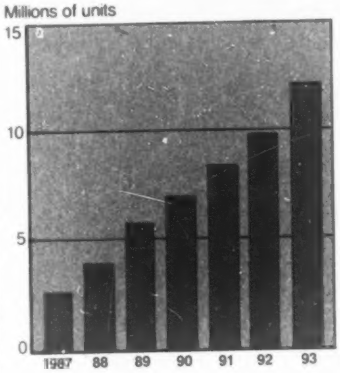
The numerous manufacturers of

catalysts offer a wide range of materials and services. Many producers make catalysts only for merchant sale. Others, such as oil companies whose main products are fuels, make catalysts for both internal use and for sale. Some producers only custom-make catalysts in response to inquiries.

Some distribution companies sell both U.S.- and foreign-produced catalysts. The catalyst business is quite fragmented, with many components frequently competing with each other.

After catalyst demand declined in the early 1980s, when both chemical and petroleum refining markets slumped, producers took various cost-cutting steps, such as rationalizing capacity and limiting development work. In the past two years, as processing increased and product profit-margins improved, a resurgence in capital investment and business activity resulted. Capacity to manufacture all kinds of catalysts and to develop new catalysts and processes continues to expand under pressure of the currently strong demand for chemicals, fuels, and other products. Many foreign catalyst producers have entered the U.S. market during this decade, largely through acquisition, but also by setting up their own marketing operations. The long-time U.S. producers also have expanded their catalyst product lines and capacities through acquisition and by building new units.

West Europe market rising for auto emission catalysts



Source: Frost & Sullivan

West Europe market will soar for emission control catalysts . . .

$ Million	1987	1990	1993
Chemical processing	$403	$ 432	$ 463
Crude oil refining	207	216	235
Emission control	248	650	1085
TOTAL	$858	$1298	$1780

Source: Frost & Sullivan

. . . but will grow slowly for chemical processing catalysts

$ Million	1987	1990	1993
Polymerization	$151	$163	$178
Oxidation	108	111	115
Organic synthesis	46	51	56
Synthesis gas	44	48	51
Hydrogenation	43	47	51
Dehydrogenation	11	12	13
TOTAL	$403	$432	$463

Source: Frost & Sullivan

Among the rash of developments in the catalyst business is this week's announcement by Degussa of an expansion program. Degussa plans to build a new facility in South Plainfield, N.J., to make a wide variety of precious metal catalysts for use in fixed-bed chemical processes. At the same site, Degussa will build its first catalyst development and technical center outside West Germany. At Calvert City, Ky., the company also plans to expand a plant recently acquired from Air Products & Chemicals that makes automobile emission-control catalysts. This expansion follows an earlier expansion at Degussa's Burlington, Ontario, plant where monolith catalysts are made for auto emission control.

Another recent development in the catalyst business is the breakup and sale of Harshaw-Filtrol, once owned by KaiserTech, a leveraged buyout of the former Kaiser Chemical. Harshaw-Filtrol was split because of concerns of possible antitrust actions by the U.S. Justice Department. Engelhard purchased the Harshaw part more than a year ago and has nearly completed the integration of Harshaw. The addition brings many base metal catalysts into Engelhard's product line, thereby expanding the line to what the company believes is the broadest range of catalysts in the world. The company also has just announced two new series of fluid catalytic cracking catalysts designed to provide higher octane-value cracked gasoline while retaining optimum yield from feedstocks.

The remaining Filtrol Corp., still owned by KaiserTech of Oakland, Calif., apparently will become a part of Akzo. In April, Akzo reached an agreement with KaiserTech to purchase Filtrol, a large producer of catalysts for fluid catalytic cracking. The Filtrol addition is expected to broaden Akzo's catalyst business, which includes various olefin polymerization catalyst systems and free radical initiators for vinyl chloride polymerizations, as well as an extensive line of cracking catalysts for petroleum refining.

Davison Chemical, a division of W. R. Grace, is another company with an expansion program for fluid catalytic cracking catalysts. Construction plans are under way for a plant with capacity of 45,000 tons per year of catalysts for fluid catalytic cracking. The plant will be located at Davison's manufacturing complex at Lake Charles, La.

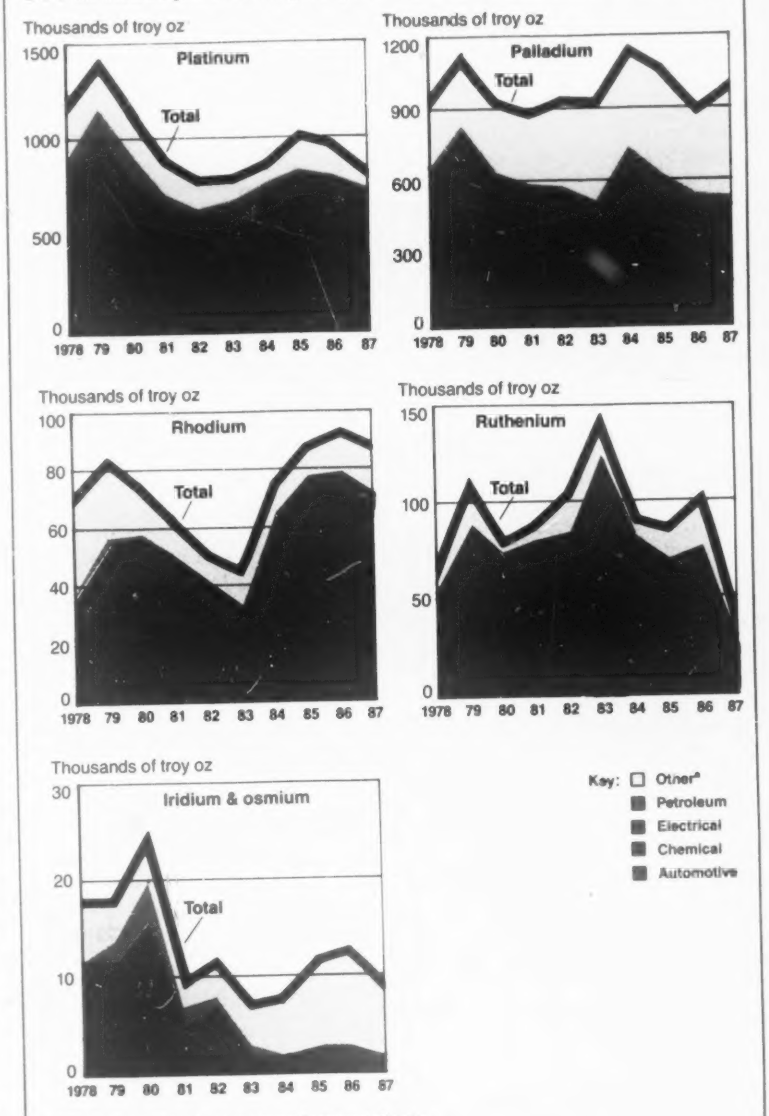
Other changes are occurring in this small but vital industry made up of about 100, mostly small, companies, most in the U.S. Many of the 30 to 40 larger catalyst companies are subsidiaries of chemical and oil companies. Five companies make catalysts for motor vehicles, and they sell to almost as few customers. About twice as many companies are major suppliers to the refining industry, including some of the oil companies. The chemical catalysts producers are much more fragmented, with many small producers making specialty catalysts for a limited market of a few reactions. The life of the small producing company frequently is short, as the developing product lines attract large catalyst companies. Small companies often are acquired by larger companies headquartered both in and outside the U.S., as a way to enter another part of the catalyst business or to expand capacity in an existing product line.

Methods of marketing catalysts are changing rapidly, too. In the past, suppliers provided data about their catalysts, leaving the customer to evaluate the catalysts and possibly to request an adaptation to a particular need. Or, customers would develop catalysts or buy processes under license and ask manufacturers to make the desired catalysts.

Marketing catalysts now requires a clear understanding of the customer's needs, a constant improvement in catalyst performance, and much customer service. Most catalyst sales staffs are technically trained, and normally they deal with the development, engineering, and technical operating personnel rather than with centralized purchasing departments of customer companies. In new commercial catalyst development, collaboration between suppliers and customers occurs on levels as high as those of other technical aspects of the chemical and refining industries.

Strategies for marketing catalysts vary significantly among the major consuming industries. In the automotive industry, for example, the few customers and the few alternatives to existing catalysts for emission control make the barrier high for entry by a new supplier. The petroleum refining industry has more customers than the automotive industry, but relative size of the companies is still large. Marketing to refiners requires dealing with several large and geographically diverse organizations, many of which operate quite similar units and processes. In contrast, the many more chemical processing companies range from small to very large, requiring marketing methods able to handle a wide spectrum of customer needs.

Consistent performance of catalysts means more today than a few years ago, because most companies using catalysts have become highly quality conscious. If one company's catalysts have established a performance record of consistency and efficiency, then, to gain a sale, a different supplier must show that a change to its catalysts will give more than a moderate cost savings.



Use of most platinum group metals has declined recently

a Jewelry, dentistry, miscellaneous. **Source:** Department of Interior

Some catalyst producers entered the business to make catalysts for chemical and refining processes that they had developed, either alone or with an engineering or research organization. They continue to develop processes for these industries and catalysts for the processes, as a way to utilize expertise built up over time. This kind of process development has led to expansion in the catalyst business and is expected by many industry sources to be a major driving force for future catalyst business expansion.

Chemical processes that use catalysts include polymerization, oxidation, reforming (or synthesis gas production), hydrogenation, dehydrogenation, and synthesis (or alkylation). Frequently, two distinct chemicals are used as catalysts. For example, in olefin polymerization using Ziegler-Natta technology, an aluminum alkyl and a titanium halide make up the system. In some cases, a reaction occurs between the components of the catalyst system to give a third member of the system.

Conversion processes in petrole-

Various factors affect potential use of enzymes in industry

Advantages	Limitations
Catalytic efficiency	Cost
Few by-products	Lability
Mild conditions	Product inhibition
Reaction selectivity	Rigid selectivities
Stereoselectivity	

Source: Perry A. Frey and Hans Liao, University of Wisconsin

um refining require catalysts, whereas separation processes do not use them, but separations are essential in providing the feedstocks for the conversion processes. Many of the catalytic processes of refining are the same as those used in chemical processes but are used to different degrees. Polymerization, for example, was an important refining process during the 1930s, but now it is a minor part of petroleum processing. Cracking, seldom used in chemical processing, continues to be the most important catalytic process in refining. Other catalytic refining processes are alkylation (which has largely supplanted polymerization), hydrotreating in several forms, and reforming (including isomerization).

Polymerization processes using catalysts (including free radical initiators) account for the dominant share of the value of catalysts used in chemical processes, at about half of the total, according to another study on the U.S. markets for catalysts used in chemical processing and petroleum refining prepared by Frost & Sullivan. Catalysts used in polymerizations are more expensive than catalysts used in several other chemical processes. However, as their activities, or efficiencies, continue to rise rapidly, they are holding down, and maybe reducing, those costs. Industry sources expect efficiencies of polyolefin catalysts on the average to be doubled over the next five years.

Estimates of efficiencies of polymerization catalysts vary widely. These estimates, forecasts for output of various polymers, and projections of costs of catalysts form the basis for forecasting both the value and quantity of catalysts to be used in the future. The forecasts for catalyst use generally are made for the active catalysts and do not include the relatively large quantities of support materials that are a part of most catalyst systems.

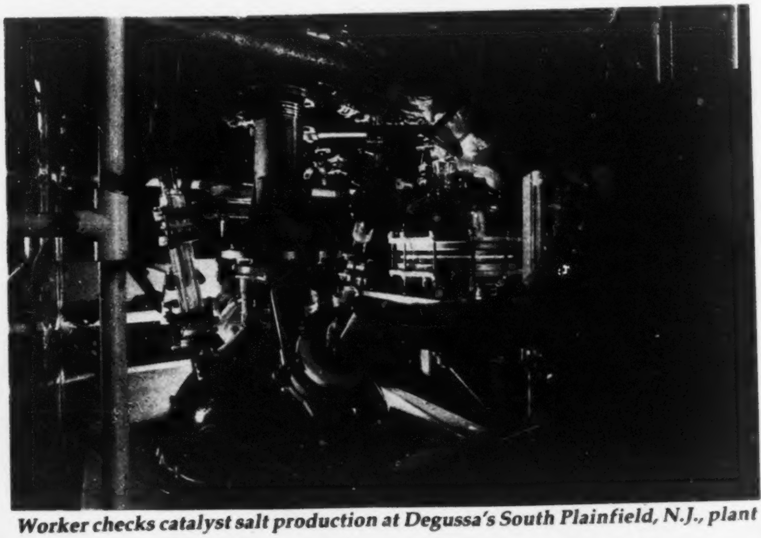
For example, in the polyolefin catalyst industry, the Ziegler-Natta systems produce about 10,000 lb of polymer per lb of catalyst (active agent and support), according to Frost & Sullivan. This efficiency is forecast to double over the next five years. The Phillips process for making high-density polyethylene may have an efficiency of about 10,000 lb per lb of a chromium oxide-type catalyst.

In polypropylene manufacture, using Ziegler-Natta technology, polymer production jumped from less than 1000 lb per lb of catalyst in the early commercialization stages to 20,000 lb per lb currently, with an additional step to 40,000 lb per lb of catalyst now under way. When polypropylene initially was commercialized, the polymer was washed to remove the spent catalyst, especially the titanium halide, because it gave undesirable color to the polymer. Now, with few exceptions, polyproplyene isn't washed because the residual catalyst content is so small that it gives few undesirable properties.

Other major volume polymers—such as low-density polyethylene (and now linear low-density polyethylene that uses a Ziegler-Natta-type catalyst system), polyvinyl chloride, and polystyrene—are made by using a free radical initiator system based on organic peroxides. Most of these polymerizations consume initiators or catalysts at the rate of about 1 lb per 1000 lb of polymer. The organic peroxides used cost $2.00 to $3.00 per lb.

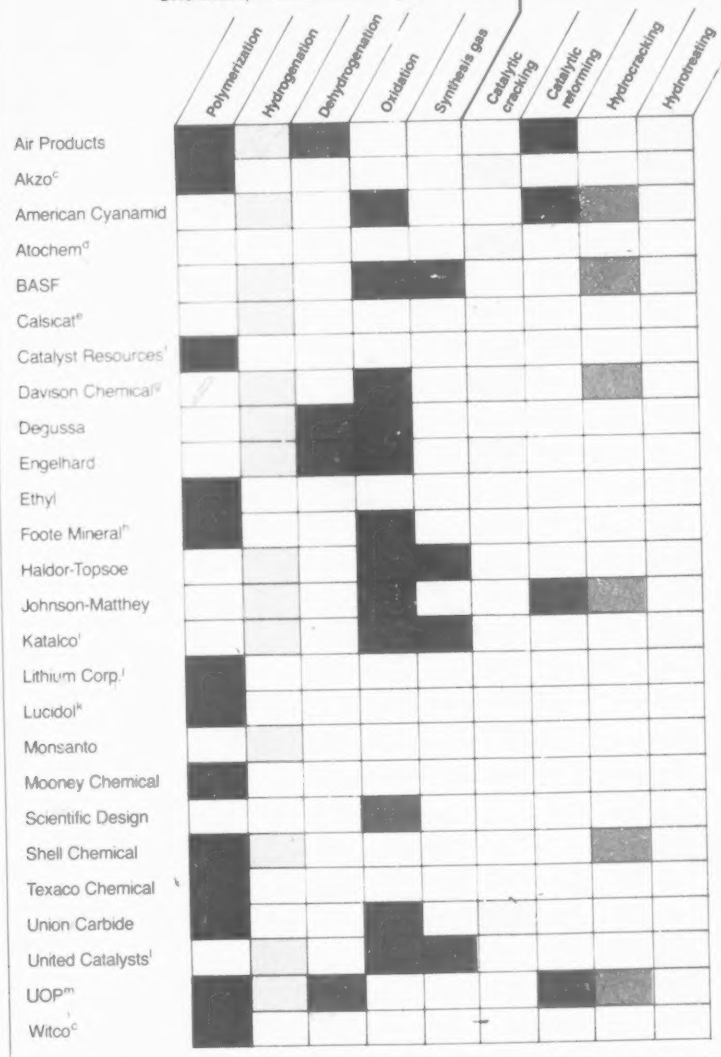
Oxidation catalysts are a distant second to polymerization catalysts in market value. Production of several large-volume chemicals incorporates oxidation as the key step in their manufacture: ethylene oxide, nitric acid, sulfuric acid, phthalic anhydride, acrylonitrile (using the ammoxidation process), formaldehyde, and vinyl chloride (using the oxychlorination process). Most of the catalysts used in commercial chemical oxidation processes are metals or metal oxides on various supports.

Sulfuric acid is by far the largest volume chemical produced by oxidation. With few exceptions, most sulfuric acid produced in the world is made by burning sulfur to produce the dioxide and then oxidizing the dioxide to the trioxide using a vanadium pentoxide catalyst on a diatomaceous earth carrier. Sulfuric, in turn, can be used as a catalyst, and worldwide demand for it in this use was between $10 million and $14 million in 1988, according to Monsanto's Enviro-Chem Systems. Growth in demand for these catalysts is forecast to be slow. Improvements continue to be made in sulfuric acid catalysts aimed at reducing resistance to gas flow with-



Worker checks catalyst salt production at Degussa's South Plainfield, N.J., plant

Major suppliers offer catalysts for variety of processes



	Chemical, environmental processes[a]					Petroleum refining[b]			
	Polymerization	Hydrogenation	Dehydrogenation	Oxidation	Synthesis gas	Catalytic cracking	Catalytic reforming	Hydrocracking	Hydrotreating
Air Products	■	░	■				■		
Akzo[c]	■								
American Cyanamid		░		■			■	▒	
Atochem[d]									
BASF		░		■	■			▒	
Calsicat[e]		░							
Catalyst Resources[f]	■								
Davison Chemical[g]		░		■				▒	
Degussa		░	■	■					
Engelhard		░	■	■					
Ethyl	■								
Foote Mineral[h]	■			■					
Haldor-Topsoe		░		■	■				
Johnson-Matthey		░		■			■	▒	
Katalco[i]		░		■	■				
Lithium Corp.[j]	■								
Lucidol[k]	■								
Monsanto		░							
Mooney Chemical	■								
Scientific Design				■					
Shell Chemical	■	░						▒	
Texaco Chemical	■								
Union Carbide	■			■					
United Catalysts[l]		░		■	■				
UOP[m]	■	░	■				■	▒	
Witco[c]	■								

a Excludes producers of commodity chemicals—sulfuric, hydrofluoric, and phosphoric acids, aluminum trichloride, and others—used as catalysts. **b** Excludes using commodity chemicals such as sulfuric and hydrofluoric acids. **c** Various subsidiaries. **d** Subsidiary of Elf Aquitaine. **e** Subsidiary of IMC. **f** Subsidiary of Phillips Petroleum. **g** Subsidiary of W. R. Grace. **h** Owned 80% by Newmont Mining. **i** Subsidiary of ICI. **j** Subsidiary of FMC. **k** Division of Pennwalt. **l** Subsidiary of Süd-Chemie. **m** Subsidiary of Allied-Signal. **Sources:** Frost & Sullivan, company data

out loss of properties such as activity, durability, and life.

The top-ranking oxidation catalyst, in terms of value of shipments last year, is silver oxide, used to speed manufacture of ethylene oxide. More than 6 billion lb of ethylene oxide will be made this year using a catalyst of silver oxide on an alumina support. Over the average three-year life of the catalyst, consumption is low because most of the silver is recovered during reprocessing of the catalyst. In a new ethylene oxide plant, the cost of the catalyst represents a significant part of the plant investment.

Nitric acid manufacture is next in size to ethylene oxide in value of catalyst consumption. To make nitric acid, ammonia is oxidized (burned) over a platinum group metal gauze or screen, often at the same site where the ammonia itself is manufactured. Efforts are continually made to reduce the loss of metal—mostly platinum with a small amount of rhodium and palladium—to below 0.01 troy oz per ton of nitric acid through process variations that reduce the pressure. Cost of catalysts for nitric acid production annually in the U.S. totals about $20 million.

Production of phthalic anhydride from *o*-xylene or naphthalene also uses vanadium oxide catalysts. Newer technologies for this oxidation use fixed-bed catalyst systems that reduce catalyst losses from levels that occur in older fluid-bed technologies.

Other chemical oxidations include making formaldehyde from methanol using catalysts such as iron and molybdenum oxides, and sometimes with chromium as a promoter or activator, or with silver and copper gauzes. To make acetaldehyde from ethylene, a palladium-copper chloride solution is used. Copper chloride also can be used in oxychlorination to make vinyl chloride. Ammoxidation of propylene to acrylonitrile may use other metals such as antimony as the active agent in the catalyst system.

Alkylations, sometimes called chemical synthesis, are dominated by two large-volume products. Ethylbenzene (the precursor of styrene) and cumene (the precursor of phenol and acetone) are made using aluminum chloride and phosphoric acid as catalysts. The quantities of these catalysts consumed in making the alkylation products is relatively large, possibly totaling 100 million lb this year, but their cost is low, being well under $1.00 per lb.

Steam reforming (or manufacture of synthesis gas containing carbon monoxide and hydrogen) precedes the making of two major-volume chemicals—ammonia and methanol. Several different catalyst systems are used to speed synthesis gas manufacture from steam and methane or coal. The active catalysts are mainly metals, such as iron, nickel, cobalt, and molybdenum and their oxides. Refinements in these catalysts have been developed since early this century, following commercialization of synthetic ammonia. Demand growth for these catalysts is slow because of improvements in efficiencies and the low average growth in use of ammonia and methanol.

Hydrogenation and dehydrogenation process catalysts make up about 10% of the chemical processing catalysts market. About half of the market is in nickel catalysts used in hydrogenation to saturate fats and oils. Platinum or palladium on various supports is widely used to hydrogenate benzene to cyclohexane. Other catalyzed hydrogenations make cyclohexanone from phenol, toluenediamines (for isocyanates) from dinitrotoluenes, and many kinds of fatty amines. The most important dehydrogenation process is making styrene from ethylbenzene using an iron oxide catalyst. Growth in catalyst use for the various hydrogenation and dehydrogenation processes will be slow, according to the Frost & Sullivan study.

Many other smaller volume chemical processes involve use of catalysts. Among the more important ones are hydration, dehydration, hydroformylation, and condensation. Although some of these processes may have large fractional gains in catalyst use, the total will remain small compared with other processes and will have small impact on the total catalyst market.

Important petroleum refining processes that use catalysts fall into four basic groups—cracking, alkylation, reforming (including isomerization), and hydrogenation. In petroleum refining, the largest catalyst market in terms of dollars is catalytic cracking, expected to be worth $250 million to $300 million this year. The largest refining catalyst market in terms of quantity is alkylation, requiring about 4 billion lb of mineral acids worth about $150 million.

Fluid catalytic cracking has almost entirely replaced thermal cracking of petroleum in the U.S., except for two severe forms of cracking—coking and viscosity breaking. And zeolites have replaced almost all other kinds of catalysts in cracking. A small number of fixed-bed catalytic cracking facilities remain, but their operation is limited because of the need to halt cracking from time to time to regenerate the catalyst bed by burning off deposits of coke and heavy hydrocarbons.

Most fluid catalytic cracking catalysts are proprietary zeolites on silicates. The composition of the zeolites varies widely, as do the kind of additives put on the catalysts to improve cracking. Use of additives in cracking catalysts can boost the octane value of the cracked gasoline, with minimal reduction in yield based on feedstock going to the cracking unit. Catalysts that improve the motor octane value of cracked gasoline are especially important since the phaseout of lead antiknock additives.

Minor variations in catalysts for fluid catalytic cracking units are used among refineries. The variations are a result, in part, of the competition to gain octane value in finished gasoline at the lowest cost. Fluid catalytic cracking competes with catalytic reforming and with use of compounds containing oxygen that have high-octane values, such as methyl *tert*-butyl ether.

Consumption of fluid catalytic cracking catalysts varies with each unit. Some of the newer units may consume a tenth of the catalyst volume that older units consume. Other influences on catalyst consumption include the activity of the cata-

Environmental catalysts will lead demand growth . . .

$ Million	1987	1992	2000	Average annual growth, % 1987-92
MARKET				
Emissions & pollution control	$ 501	$ 985	$2060	14.5%
Motor vehicles	476	900	1730	13.6
Industrial	25	85	330	27.7
Petroleum refining	596	710	900	3.6
Chemical manufacture	534	640	840	3.7
TOTAL	**$1631**	**$2335**	**$3800**	**7.4%**
CATALYST TYPE				
Noble metals	585	1095	2200	13.4
Platinum group	571	1080	2180	13.6
Silver	14	15	20	1.4
Base metals	401	460	560	2.8
Zeolites	282	325	390	2.9
Peroxides	210	290	465	6.7
Commodity chemicals[a]	135	145	160	1.4
Others	18	20	25	2.1
TOTAL	**$1631**	**$2335**	**$3800**	**7.4%**

. . . but volume growth will be smaller than value growth

	1987	1992	2000	Average annual growth, % 1987-92
CATALYST TYPE[b], millions of lb				
Base metals	212	240	255	2.5%
Zeolites	333	390	515	3.2
Peroxides	42	50	60	3.5
Commodity chemicals[a]	3905	4135	4275	1.2
Others	12	15	20	4.6
TOTAL	**4504**	**4830**	**5125**	**1.4%**
NOBLE METALS, thousands of troy oz				
Platinum Group	1306	1675	1980	5.1
Platinum	882	1154	1405	5.5
Palladium	345	420	460	4.0
Rhodium	59	89	105	8.6
Others	20	12	10	−9.7
Silver	2500	2250	2200	−2.1
TOTAL	**3806**	**3925**	**4180**	**0.6%**

a For example, mineral acids. b Noble metals excluded because of [illegible] Source: Freedonia Group lysts, type and properties of the feedstock to the unit (such as its sulfur content and gravity), whether or not the feedstock has been treated to improve its properties, and severity of operation of the cracking unit. Consumption is believed by industry sources to be slowly increasing because refinery fluid catalytic cracking units are being operated more severely and with higher throughput to meet gasoline demand and because the feedstocks are heavier and more contaminated with sulfur, nitrogen, and metals.

Consumption of cracking catalysts this year is forecast to range between 0.15 and 0.25 lb per barrel of feedstock. With catalytic cracking units processing nearly 5 million bbl per day, catalyst consumption could reach 400 million lb.

Nevertheless, many changes could occur in catalyst consumption this year. One uncertainty stems from the planned decrease in use of butane in gasoline to reduce its vapor pressure and emissions into the atmosphere. The butane could be put into fluid catalytic cracking units to produce more olefins and isobutane for alkylation or for chemical uses. Another uncertainty is the possible use of more residual oil in catalytic cracker feedstocks to reduce the amount of this oil that must be sold in competition with lower cost natural gas. The heavier and generally more contaminated residual oil, if used, would tend to increase catalyst consumption in cracking units.

Catalytic reforming of various naphthas converts these low-octane petroleum fractions to high-octane, highly aromatized gasoline components. Some of the aromatics are separated from the reformate to supply aromatics used as chemical raw materials. About half of the U.S. components of gasoline now come from catalytic reforming. Currently, platinum and another metal—often rhenium or iridium—account for

Key properties determine performance of catalysts

Activity. Measured as the quantity of reactant in contact with a catalyst under given process conditions.

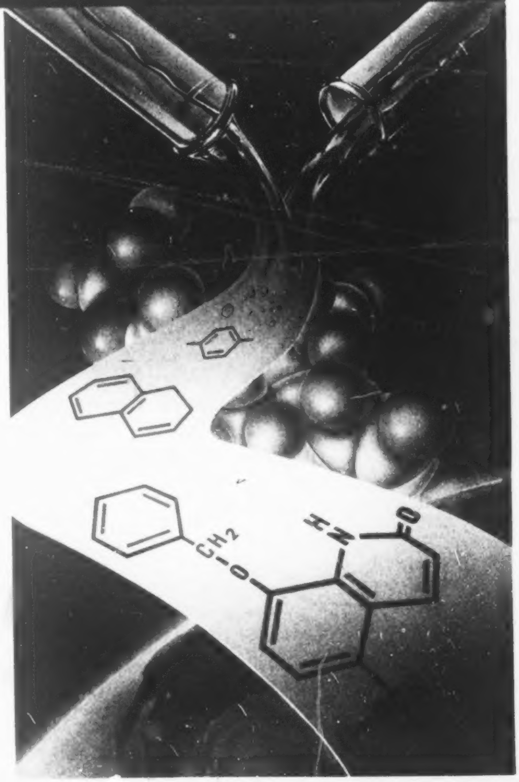
Physical Stability. Measured by at least three standards: retention of porosity and of structure under given process conditions and retention of mechanical strength, an indication of resistance to handling forces.

Regenerability. Measured as how well catalysts regain activity and selectivity after removal of deposits of substances that reduce such properties.

Selectivity. Measured as efficiency of catalysis by determining yield of products relative to quantity of reactants.

Stability. Measured as how well catalysts retain activity and selectivity over their life span.

Source: Frost & Sullivan



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most reforming catalysts, having supplanted the initial reforming catalysts made of silica-molybdena used in the 1950s and 1960s. These catalysts are expensive, but the quantity consumed per barrel of gasoline is small, making the value of these catalysts a tenth of that of catalytic cracking catalysts.

The longer term outlook for reforming catalysts is better than it was three years ago. Reduction in gasoline volatility, by reduction of high-octane-value butane in gasoline, requires that other high-octane components replace butane. Aromatics in reformate are expected to be one of two major sources of these components. To increase output of reformate, the catalytic reforming units will be operated more severely, which will reduce yields and consume more catalyst.

Alkylation will be another source of additional high-octane components. Almost all refinery alkylation processes that combine a small olefin (butene) with a small paraffin (isobutane) to make a larger paraffin in the gasoline range of hydrocarbons are catalyzed with either sulfuric or hydrofluoric acids. The petroleum refining consumption of these acids, although large

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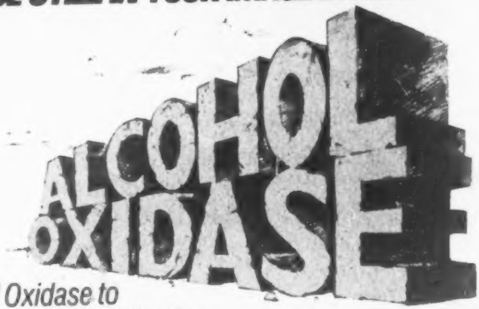

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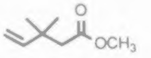
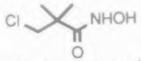
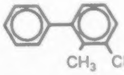
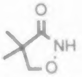
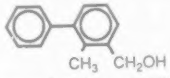
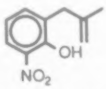

Methyl dimethylpentenoate

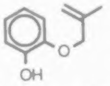

Hydroxamic acid

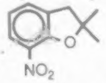

Methylchlorobiphenyl (MCBP)

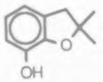

Isoxazolidinone

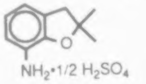

Hydroxymethylbiphenyl (HMBP)


2-Methallyl-6-nitrophenol


2-Methallyloxyphenol (MOP)


7-Nitrobenzofuran (7-Nitro)


7-Hydroxy


7-Aminobenzofuran sulfate

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CIRCLE 36 ON READER SERVICE CARD

Demand for petroleum refining catalysts will grow steadily

$ Million	1982	1987	1992	2000
Catalytic cracking	$235	$260	$310	$400
Alkylation	140	144	165	190
Hydrotreating	65	88	105	130
Hydrocracking	38	65	80	110
Reforming	20	32	40	55
Other	4	7	10	15
TOTAL	$502	$596	$710	$900

Millions of lb	1982	1987	1992	2000
Catalytic cracking	351	376	440	530
Alkylation	3885	3900	4125	4270
Hydrotreating	26	30	35	40
Hydrocracking	3	5	6	8
Reforming	4	5	6	8
Other	1	2	3	4
TOTAL	4270	4318	4615	4860

Source: Freedonia Group

in volume relative to consumption of other catalysts, is a small part of total consumption of these acids. Demand for these acids as alkylation catalysts varies partially with the level of operation of alkylation units. Alkylation varies with a refinery's supply of suitable olefins and paraffins.

Two catalyzed treating processes using hydrogen are growing slowly as consumers of catalysts. Hydrotreating consumes several times the volume of catalysts that hydrocracking does, because hydrotreating almost entirely uses base metal catalysts. The value of hydrotreating catalysts is only about 50% more than the value of hydrocracking catalysts, because some platinum group metals are used in hydrocracking catalysts. Hydrogen supply in refineries and competition from other processes, such as catalytic cracking and reforming, had been limiting growth of these two processes.

A more favorable outlook for these processes could boost catalyst consumption. The quality of crude oil for making gasoline generally will decline, causing refiners to hydrotreat feedstocks having higher contents of sulfur and nitrogen compounds. Hydrotreating (or simply, hydrogenation) removes the sulfur and nitrogen atoms. It also saturates part of the olefins and removes oxygen-containing compounds. A hydrotreated gas oil often is the

Tunnel furnace at Haldor-Topsoe's catalyst plant in Frederikssund, Denmark

feedstock to a catalytic cracking unit. Hydrotreating will have to be increased if lower sulfur specifications are required for diesel fuel and other heavier fuel oils.

Hydrocracking, which includes some hydrotreating, is used to reduce the higher molecular weight hydrocarbons that are a big part of the bottom of a barrel of petroleum. Hydrocracking most often is used to prepare better feedstocks for catalytic cracking and reforming units. Usually, platinum and other similar metals on an alumina support are used, but base metal catalysts of nickel, cobalt, and molybdenum also may be used. The more expensive platinum group metals cause a much higher unit value for hydrocracking catalysts than for hydrotreating catalysts.

In the mid-1980s, hydrocracking was growing slowly because of a temporary increase in supplies of lighter, sweeter crude oils. The shift toward heavier sour crudes and the need for reformate, alkylate, and cracked gasoline now is starting a resurgence in hydrocracking. Better catalysts, however, will hold down consumption increases.

Isomerization, a relatively old refining process, is gaining favor again as the need for alkylate increases. This process usually is used in refineries to convert C_4 to C_8 straight chain hydrocarbons, most of which have relatively low octane values (*n*-heptane is the standard value for zero research octane number), to branched chain hydrocarbons with higher octane values. The sources of these hydrocarbons are natural gas liquids and the light, straight run gasoline from the initial crude oil distillation. Product from isomerization units can be separated and the heavier fraction, with an octane value of 75 to 85, can go to gasoline blending. The lighter fraction can go to an alkylation unit.

Catalysts for isomerization are similar to the platinum group metals on alumina support catalysts used for catalytic reforming. Because the volume of operating isomerization capacity is relatively small, catalyst consumption also is expected to be small, at about \$10 million to \$12 million in 1989. Restarting of shutdown isomerization units, conversion of other process units to isomerization, and new construction all are forecast to increase demand for isomerization catalysts. But because of the small base, even large increases will have little effect on the total refining catalyst market.

Under pressure to reduce emissions of hydrocarbons, carbon monoxide, and nitrogen oxides (NO_x) from automobile exhaust, demand for catalysts to reduce these emissions has increased rapidly. These catalysts are the largest segment of the catalyst business at about \$650 million in the U.S. this year. Further reductions in emission levels, demands for longer life to the catalytic converters on autos, and extension of emission controls to large trucks and buses all will combine to increase demand for catalysts, almost entirely platinum group met-

Cost of catalysts for chemical manufacture rises slowly

$ Million	1982	1987	1992	2000
Polymerization	$208	$257	315	$430
Organic synthesis	70	84	100	130
Oxidation	80	95	110	135
Synthesis gas	43	54	63	80
Hydrogenation	28	34	40	50
Dehydrogenation	7	10	12	15
TOTAL	$436	$534	$640	$840
Millions of lb	**1982**	**1987**	**1992**	**2000**
Polymerization	46	55	65	85
Organic synthesis	74	86	97	115
Oxidation	10	13	15	17
Synthesis gas	14	17	20	25
Hydrogenation	8	10	12	15
Dehydrogenation	4	5	6	8
TOTAL	156	186	215	265
Catalyst cost, average ($ per lb)	$2.79	$2.87	$2.98	$3.17

Source: Freedonia Group

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CIRCLE 29 ON READER SERVICE CARD

Most major petrochemical processes depend on catalysts

Decade Beginning	Example of process or product[a]	Example of catalysts used
1900	Hydrogenation of fats	Ni
1910	Coal hydrogenation to liquid fuels	Fe
	Ammonia synthesis	Fe
1920	Methanol from synthesis gas	Zn, Cr oxides
	Hydrocarbons from synthesis gas	Fe/Co
1930	Fixed-bed catalytic cracking	Aluminosilicates
	Ethylene oxide	Ag
	Polyvinyl chloride	Peroxides
	Low-density polyethylene	Peroxides
1940	Catalytic reforming	Pt
	Synthetic rubbers—SBR	Li or peroxides
	Nitrile	Peroxides
	Butyl	Al
1950	High-density polyethylene	Ti or Cr
	Polypropylene	Ti
	Dehydrosulfurization	Co, Mo sulfides
	Terephthalic acid	Homogeneous Co/Mn
	Hydrocracking	Pt
1960	Maleic anhydride	V, P oxides
	Acrylonitriles	Bi, Mo oxides
	Improved catalytic cracking	Zeolites
	Adiponitrile from butadiene and HCN	Homogeneous Ni
	Phthalic anhydride from *o*-xylene	V, Ti oxides
1970	Methanol from synthesis gas	Cu, Zn, Al oxides
	Acetic acid via methanol and CO	Homogeneous Rh
	Linear low-density polyethylene	Ti, Cr
	α-Olefins via ethylene oligomerization	Homogeneous Ni, Mo/W
	Improved hydroformylation	Homogeneous Rh
1980	Methanol to gasoline	Zeolites
	Acetic anhydride from synthesis gas	Homogeneous Rh
	Methylmethacrylate from *tert*-butanol	Mo oxide
	Improved coal liquefaction	Co, Mo sulfides
	Improved coal gasification	Various metal salts

a C&EN selected examples. **Source:** G. Alex Mills, University of Delaware

als. If other industrialized countries follow the limits to auto emissions now in place in Japan and the U.S., and coming soon in Western Europe, the demand for emission control catalysts could jump again in the next decade.

The increased demand for emission reduction has led to greatly increased prices for these metals. Further increases are forecast. The Frost & Sullivan catalyst study for the U.S. puts the cost of a catalytic converter at about 2% of the total cost of a current, medium-priced automobile. If longer life and lower emissions are required, especially of nitrogen oxides, the converter could become 5% of the cost of a car. Much of the cost increase would result from increased use of rhodium in the catalyst, because this metal reduces NO_x better than other platinum group metals.

Further reducing industrial and power plant emissions also will increase catalyst demand. The value of the catalysts for industrial emission control, expected to be a small part of the total costs of emission control, could rise rapidly. The Freedonia Group estimates that industrial emission controls will require catalysts worth $85 million by 1992, up from $25 million in 1987, and nearly quadrupling to $330 million by 2000.

Yet another area of catalysts are the biocatalysts, largely enzymes. A few industrial processes, such as sugar transformations, semisynthesis of antibiotics, and transformations of steroids, are catalyzed by enzymes. The value of enzymes used as catalysts is estimated at $100 million to $150 million this year. Several barriers to their use include high cost; liability to heat, variations in pH, and solvents; and often a narrow selectivity, according to Perry A. Frey of the Institute of Enzyme Research at the University of Wisconsin.

Use of genetic engineering to aid enyzme production and to increase thermal stabilities, as well as to design specificities, remains in its in-

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fancy, according to Frey. Some early results of work in this field suggest that enzymes could become increasingly versatile catalysts for certain applications. Large-scale use will come, but it will take time.

Improvements in catalysts and catalytic processes to produce fuels and chemicals hold down growth in both volume and value of catalysts. In the area of chemicals, James A. Cusumano, chairman of Catalytica, a firm that specializes in development of catalysts and processes in Mountain View, Calif., points out numerous examples of changes in routes to well-known products. For example, improved catalysts are leading to more efficient butane oxidation for making maleic anhydride, including use of fluidized-bed technology. Other possibilities include direct oxidation of benzene to phenol (thereby bypassing cumene), carboxylation to make methyl methacrylate (avoiding use of cyanohydrin), and conversion of maleic anhydride to make 1,4-butanediol (avoiding use of acetylene).

In the petroleum refining processes, several developments will be coming, Cusumano says. One will be catalysts that improve isomerization by operating at lower temperatures. In naphtha reforming, new catalysts to partially replace platinum group metals will be developed using designs to adjust the acidity on the surface (either inside or outside the pores).

Emission control catalysts also are being improved. Catalysts currently are being developed to aid processes that handle very low concentrations of organic compounds and oxides of sulfur and nitrogen. Other catalytic processes also are being developed to efficiently make fuel components, such as methanol and other oxygenates that reduce exhaust pollutants.

Further development of catalysts for these and other uses will likely keep the catalyst business on a long-term growth curve. As long as chemical reactions are used in processes to make products or handle wastes, catalysts will be crucial to economic success of the processes. The 0.1 to 0.3% of product costs spent on catalysts for processing has proved to be an excellent value. □

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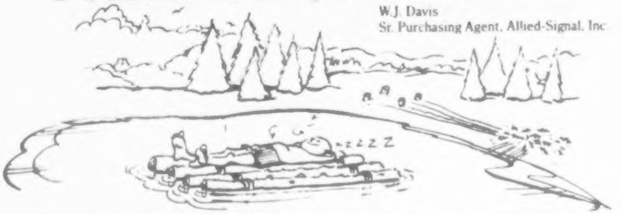
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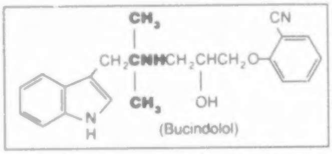

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CIRCLE 17 ON READER SERVICE CARD

JUNE 5, 1989

CHEMICAL & ENGINEERING NEWS

Cornell's Roald Hoffmann wins 1990 Priestley Medal

Page 19

A1250-1

CHEMICAL & ENGINEERING NEWS

Volume 67, Number 23
CENEAR 67 (23) 1–48
ISSN 0009-2347

JUNE 5, 1989

News of the Week

- **Undergrad engineering programs in 1988 record first gains in freshman enrollments since 1982, largely owing to strong increase in minority students.** Page 4

- **Water-based process for making polyurethane foams without using chlorofluorocarbon blowing agents is now being offered by BASF.** Page 5

- **Dutch government unveils a tough and costly antipollution program that could strongly affect the chemical industry.** Page 5

- **Coalition of organizations hits EPA with a suit and petition aimed at revoking rules permitting residues of several pesticides in processed foods.** Page 6

- **NSF group finds that over half of the investigators whose proposals for interdisciplinary engineering research centers had been rejected ended up benefiting from the experience.** Page 6

Business

Chemical industry is one of the bright spots in a basically dismal picture of U.S. industry drawn in a study by a Massachusetts Institute of Technology group. **Page 9**

Government

Much higher funding of science education by the National Science Foundation and more scientists' time devoted to educational concerns are urged by NSF official Bassam Shakhashiri. **Page 12**

Academia needs greater awareness of hazardous wastes handling and appropriate regulations, concludes EPA in a study of how schools are managing disposal of such wastes. **Page 13**

Science/Technology

Experiments to further define cold fusion continue to baffle researchers gathered at recent fusion workshop. **Page 16**

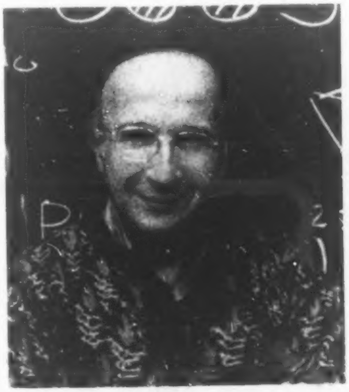
Twenty finalists will vie for four places on U.S. team for International Chemistry Olympiad. **Page 18**

Books

Autobiography of Francis Crick aims to illustrate special character of biological research and to show research as a human activity. **Page 22**

ACS News

Official reports of ACS committees that met in Dallas during ACS national meeting. **Page 27**



Priestley Medal

Roald Hoffmann, a professor at Cornell University and winner of ACS's 1990 Priestley Medal, is an avid researcher, poet, essayist, and soon-to-be TV host. Page 19

Letters 2

Concentrates
Business 7
Government 11
Science/Technology 15

The Departments
People 34
Newscripts 48

Chemical & Engineering News

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LETTERS

Electronic databases

SIR: I have read the letter by Stuart M. Kaback and the CAS reply by Newman M. Bortnik on the distribution of Chemical Abstracts Service's electronic databases (C&EN, Feb. 6, pages 3, 34). The actions taken by CAS to restrict access to its databases are particularly dismal, because much research today is multidisciplinary. I routinely search chemical, medical, and engineering databases.

If the CAS actions become a trend, many database compilers will become vendors, and scientists will find themselves subscribing to separate search services for each database. To comprehend how undesirable this is, imagine this trend applied to distribution of the hardcopy versions of the electronic databases. Research scientists would find themselves going to one library for *Chemical Abstracts*, a second one for *Index Medicus*, and yet a third to consult *Engineering Index*.

Actually, research libraries concentrate abstracts (and journals) in one place, where scientists with wide-ranging minds can gain access to information as quickly as they recognize the need for it. I think electronic databases should retain this efficient concentration.

John H. Cross
Houston

Nuclear fusion

SIR: Here are a couple of thoughts on the fusion confusion. I have worked with hydrogen gas and thin-walled palladium tubes (for the removal of dissolved hydrogen gas from water). The solubility and mobility of hydrogen into and through palladium is mind-boggling.

My first thought is: If the calculation of the amount of heat that is supposed to be generated is based on the number of neutrons measured, perhaps not all of the neutrons being generated escape to be measured, and it would therefore appear that more heat is being generated than the calculations permit. If hydrogen is being generated electrolytically (and is being absorbed into the palladium) for five days before the effect is observed, it has to be more crowded in there than 19 college students stacked into a stand-alone phone booth. The higher the density of atomic nuclei, the greater the chances of neutrons being soaked up and therefore not being measured.

The other thought is to place a palladium tube inside another metal tube, make a bomb out of it, then evacuate the bomb, fill it with deuterium gas, and keep it under slight pressure for a few days. If nothing happens, increase the pressure, and if still nothing happens, it kind of tells one that, if the fusion reaction actually occurs, it does so with nascent deuterium. This might lead one to make the electrolysis go at a voltage that is just below that at which gas is evolved, and use a piece of palladium with a lot of surface area. The fusion reaction may also have a critical volume.

Other things I have done during the past 47 years after graduation cause me to heartily urge everyone to clean the palladium with a 600 °C vacuum bake immediately before it is used in any experiment of this nature. This was suggested by someone else, and is an excellent idea. A metal as active as palladium can fill its active sites with garbage, especially if it sits around a laboratory for a while.

Keith R. Whitcomb
El Cajon, Calif.

Polyhedron carbon clusters

SIR: Interest in the large polyhedron carbon clusters (C&EN, Aug. 29, 1988, page 33) has drawn attention to buckminsterfullerene. The generalized geodesic dome shape is familiar to all of us.

I am writing to express an idea in the above area based on the π-metallocenes. If the faces of an appropriate polyhedral cluster possessed aromaticity à la ferrocene, then a rodlike half of ferrocene would extend outward from at least several faces; hence, "pincushionene."

Richard E. Bozak
California State University, Hayward

Future of nuclear power

SIR: Two letters published in your fine magazine (C&EN, Dec. 12, 1988, page 2, and March 6, page 2) by Mike McCormack and Claude R. Hudgens read like forlorn missives from Japanese World War II survivors stuck on remote islands who haven't yet heard about the surrender. Both aim small arms fire at opponents of atomic power as if the nukes were still a viable answer for our energy needs.

Apparently the writers have yet to hear about Three Mile Island, Chernobyl, the cancellation of more than 100 U.S. reactor projects—including Zimmer and Shoreham—and similar cancel-

NSF's Shakhashiri Pushes for More NSF Funding, Time for Education

Target is about $600 million per year—20% of agency's present budget—and 10% of researchers' time devoted to science education

Bassam Z. Shakhashiri, assistant director for science and engineering education at the National Science Foundation, is not shy about asking for what he wants. And what he wants for science education is more money and more time: 20% of NSF's budget and 10% of scientists' time. The twin problems of scientific illiteracy and a shrinking supply of new science professionals cannot be addressed adequately without both of those, he believes.

Since coming to NSF five years ago from the University of Wisconsin, Madison, where he founded the Institute for Chemical Education, Shakhashiri has been relentless in pressing his case within the agency, the White House, and Congress for more funds for science education. He has just as consistently lobbied academic scientists to reserve more time from their research to devote to educational concerns.

But the once seemingly tireless chemist now seems weary and frustrated at times. "I feel for the most part satisfied in what I've accomplished in the past five years," Shakhashiri says. "Is the job done? No. We've made good progress. But I don't want progress. I want advances. As long as I feel I can be effective I will continue here, but I'm eager to go back to classroom teaching."

At NSF, Shakhashiri has presided over the rebuilding of the education directorate, which the Reagan Administration abolished in the spring of 1982. At that time, the agency scrapped all of its education programs except some graduate fellowships and awards, preferring to concentrate on funding basic research in science and education.

In fall 1983, however, the directorate for science and engineering education was reestablished amid growing fear that the future of the U.S. was threatened by the weak state of U.S. education in general. The directorate received $171 million in fiscal 1989—almost 9% of NSF's budget and about the same proportion it commanded a decade ago. The Administration has requested $190 million for the directorate for fiscal 1990, again about 9% of NSF's total budget.

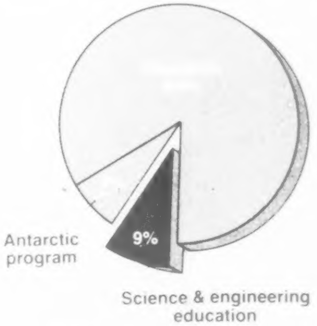
That is well below the 40% share that education received in its heyday in the late 1950s, however, and well below what Shakhashiri says could be put to good use now. "The NSF level of effort for science education should be about $600 million a year, $300 million for precollege programs, $200 million for college programs, and $100 million for graduate fellowships and traineeships. If the NSF budget doubles over the next several years to about $3 billion altogether, $600 million for education would be 20% of that."

American Chemical Society president Clayton F. Callis supported that $600 million target—a figure suggested by two reports of the National Science Board—in testimony before Congress last month (C&EN, May 22, page 39). "This nation must strengthen and emphasize science education at all levels in order to maintain and improve our competitive position worldwide and to provide the technically literate work force needed in the future," Callis said. Calling the $190 million requested for 1990 insufficient, ACS asks that the education directorate be funded at $231 million next year.

For the past several years, Congress has given more money to the NSF education directorate than the Administration requested. Earlier this spring, Jerry A. Bell—professor of chemistry at Simmons College in Boston, current director of the Institute for Chemical Education, and an NSF education administrator from 1984 to 1986—thanked Congress for its support during a hearing held by the House Committee on Science, Space & Technology's Subcommittee on Science, Research & Technology.

"I assure you that without the help of this Subcommittee and that of the Congressional Committees on Appropriations, the NSF budget for science, engineering, and mathematics education would still be very small," Bell said. "Since 1985 the Administration's requests for science education have displayed a dismal lack of leadership."

Science education gets about 9% of NSF funds



Fiscal year 1988 total = $1.9 billion

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C&EN staff photo

Shakhashiri: job not yet done

Pending the passage of the 1990 budget, Shakhashiri has two major programs in the planning stages. They are a state initiative and an urban initiative in science, mathematics, and technology education. "These will be a systematic approach to try to work with state governors, business leaders, and the education community to elevate the level of scientific literacy," he says.

"At the same time, we will work with people in big urban settings to address problems characteristic of those settings, like high dropout rates," Shakhashiri says. "We'll try to get university scientists and scientists from industry to work with the 100 largest school districts. We want a collaborative effort among institutions of higher education, state educational institutions, and the private sector to put in place a sustained set of activities aimed at improving science and math education."

Shakhashiri believes strongly that working scientists should get much more involved in science education issues. "We can't just sit back and let somebody else worry about it," he says. "We want to be sure we have the right human resources available to meet the demands of the 21st century. I'd like to see people from the chemistry department at Columbia University, say, pay some attention to how chemistry is taught in New York City. I could say the same thing about the University of Chicago, or Houston, or UCLA."

The current culture in universities, he thinks, does not place a high enough value on teaching at the college or precollege level. He'd like to see academics devote 10% of their time to educational issues. Many of the programs the NSF education directorate has devised are mechanisms to bring together scientists with educators.

"We have a huge budget deficit and a huge trade deficit," Shakhashiri says. "But we don't have a brain deficit in this country. We need to encourage the talent in this country to pursue careers in science or—for those who choose not to—to at least be tolerant if not supportive of what scientists want to do."

Pamela Zurer

EPA examines schools' handling of toxic waste

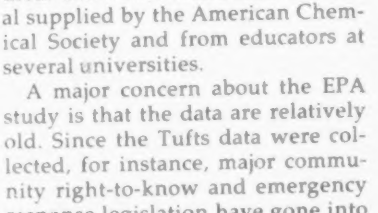
The Environmental Protection Agency, in a just-completed report to Congress on the state of hazardous materials handling at academic institutions, concludes that most problems arise from the institutions' lack of awareness about hazardous wastes and appropriate regulations. Most recommendations focus on increasing that awareness.

Entitled "Report to Congress: Management of Hazardous Wastes from Educational Institutions," the report was ordered in the 1984 amendments to the Resource Conservation & Recovery Act. Congress asked that the report be completed by April 1987, a deadline missed by only two years. EPA emphasizes that the report is only factual in nature, as the agency was not directed by Congress to develop regulatory programs or statutory changes to control wastes in school labs. The report includes an analysis, based on data the agency received from school labs, of the methods available for treatment and disposal of academic hazardous wastes.

EPA estimates that about 30,000 universities, colleges, and high schools in the U.S. generate up to a total of 4000 metric tons of hazardous wastes annually. This is less than 0.01% of the 240 million metric tons of total hazardous wastes estimated to be generated in the U.S. each year. The very small percentage is one of the reasons that this report was requested. When RCRA was being reauthorized, organizations concerned about the rigidity of current rules for disposal of hazardous wastes as they applied to academic labs wanted Congress to set different disposal rules for schools than for industry. The EPA study was a step to get the government to recognize that academic labs are not comparable to industrial labs.

Most of the data EPA relied on to prepare its report was collected under a contract from Tufts University, completed in 1987. The Tufts group made a study of 26 institutions—19 colleges and universities and seven high schools—of various sizes and in different localities. The study looked at what wastes were generated and how they were handled. Other data came from material supplied by the American Chemical Society and from educators at several universities.

A major concern about the EPA study is that the data are relatively old. Since the Tufts data were collected, for instance, major community right-to-know and emergency response legislation have gone into effect. These are included in Title III of the Superfund Amendments & Reauthorization Act of 1986. The recent legislation has heightened



Bulk of lab wastes that can't be treated is placed in lab packs for disposal

PRELIMINARY PROGRAM
ACS national meeting
in Miami Beach Page 101

Advance information for
PACIFICHEM '89 in Honolulu Page 120

JUNE 19, 1989

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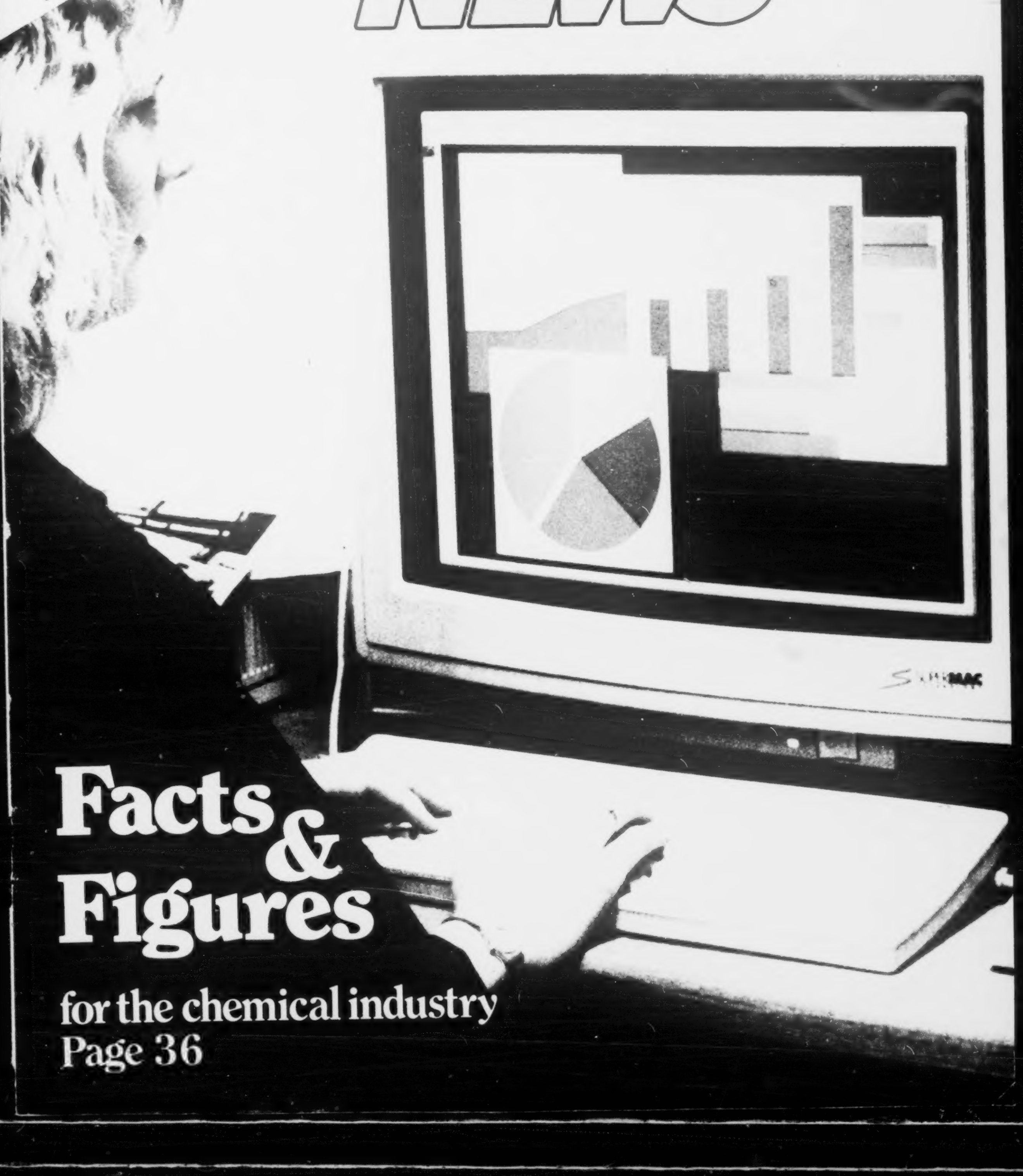

Facts & Figures

for the chemical industry
Page 36

CHEMICAL & ENGINEERING
NEWS

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JUNE 19, 1989

News of the Week

- **President Bush offers array of sweeping but costly programs to deal with acid rain, smog, emissions.** Page 5
- **House panel investigating ethics in the science research community grills MIT's president on school's industrial liaison program.** Page 6
- **Scientists at Virginia Polytechnic Institute develop new catalyst useful in commercially important hydroformylation reactions.** Page 7
- **U.S.-China science, business relations chill following Chinese crackdown on pro-democracy demonstrators.** Page 8

Cover: Photo by C&EN's David J. Hanson

Letters 4

Concentrates

Business 13
Government 18
Science/Technology 29

The Departments

New Products 27
ACS Comment 91
Awards 125
Newscripts 140

Business

Portugal's opening of its chemical industry to foreign investment and plans for single European Community market in 1992 were focus of CEFIC meeting in Lisbon. Page 15

Government

Occidental Chemical agrees to store and destroy wastes from Love Canal; Coalition for National Science Funding issues report calling for sustained funding of basic science research. Page 20

Science/Technology

Superconductor research leads to development of new devices; more research into fluid catalytic cracking, fluidization urged; improving the reliability of forecasting recommended as way to better global warming predictions. Page 30

ACS News

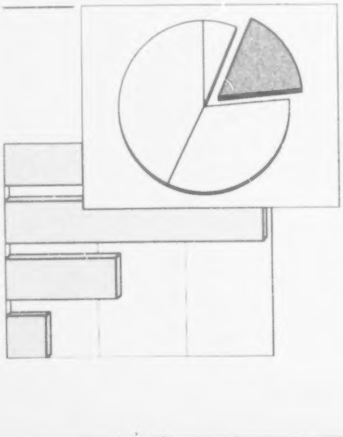
Committee on Professional Training reports on 1988 bachelor's, masters, and Ph.D. graduates of ACS-approved schools; University of California, Berkeley, was top producer of Ph.D. chemists. Page 93

Preliminary Program

198th ACS national meeting in Miami Beach: list of symposia, advance registration form. Page 101

Meetings

Advance information on the International Chemical Congress of Pacific Basin Societies in Honolulu, Dec. 17-22. Page 120



Facts & Figures

A banner year was chalked up by the chemical industry in 1988, both in the U.S. and worldwide. Output advanced smartly, profitability was much improved, and other business trends generally were favorable. C&EN's annual statistical package details recent progress. Page 36

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LETTERS

Parliament reversed

SIR: It should be noted that the cover photograph on the March 6 issue of C&EN is reversed. The picture is taken facing north towards the Ottawa River. The outlet of the Rideau Canal, famous in connection with certain unmentionable events involving our two countries in 1812, should lie to the east of the parliament building—not, as it does in the photograph, to the west. Chemists visiting our capital should not use the picture to find their way around our parliament hill. The picture, like our science policy in Canada, is topsy-turvy.

Your article was most informative, and provided a perspective that was most revealing. Our government is bringing down the budget, and with the magnitude of the national debt, which is greater relative to the gross national product than yours in the states, restraint will be the keyword. Whether the government will have sufficient courage to support science more strongly than in the past is doubtful, even though improved GNP in the future will depend on support for research—especially basic research—now.

John Milne
Associate Professor of Chemistry
University of Ottawa

Pesticide risk

SIR: Your article on pesticide risk to children (C&EN, March 13, page 13) failed to investigate the science behind the hysteria. In fact, your statement that our fruits are "ladened with pesticide residue(s)," just adds more confusion and concern about our food supply system—one of the safest in the world.

Your article was based principally on a Natural Resources Defense Council report, "Intolerable Risk: Pesticides in our Children's Food." NRDC has labeled the Alar active ingredient daminozide and its metabolite, unsymmetrical dimethylhydrazine (UDMH), potent carcinogens. The scientific facts, however, do not support this allegation, and your article does nothing to reveal the real scientific facts in this case.

Daminozide is not mutagenic and not carcinogenic. Daminozide was first shown not to be carcinogenic in rats in 1966; recent studies (1988) in which daminozide was fed to rats and mice at levels up to 10,000 ppm in the diet showed no carcinogenicity. A battery of mutagenicity studies on daminozide were all negative.

UDMH was also not mutagenic in a battery of tests. Carcinogenicity studies are still in progress on UDMH in rats and mice. After one year of feeding, there is no carcinogenicity in rats at all doses, and none in mice at all doses but the highest dose. This high dose clearly exceeded the maximum tolerated dose as determined by severe liver damage leading to premature death. This high dose is 4 million times higher than human exposure. Clearly, UDMH is not a potent carcinogen, and there appears to be no health risk of cancer to humans from exposure to UDMH at low doses.

The NDRC report focused on UDMH studies published in 1973 that have been invalidated by the Environmental Protection Agency Scientific Advisory Panel, and discarded by EPA as unreliable for quantitative or qualitative risk assessment.

Alar does not pose a risk to human health. To the contrary, Alar helps growers produce healthier, higher quality apples that can be stored and enjoyed throughout the year.

J. A. Lacadie
Director, Crop Protection R&D
Uniroyal Chemical Co.
Middlebury, Conn.

Fluoridation of water

SIR: The review of the studies on fluoridation (C&EN, May 8, page 5) points up to my mind only one of the common flaws plaguing public health research.

Although the studies show little difference between populations using fluoridated vs. unfluoridated water, they do not address the real issue of how much fluoride the two theoretically different populations are actually receiving. The medical and dental community frequently compensate for lack of fluoride in drinking water. Standard pediatric practice is to prescribe vitamins with fluoride or fluoride supplements for children in unfluoridated areas. The advertising community is another source of fluoride outside the drinking water supply via fluoridated toothpastes and mouthwashes.

Fluoridation of children, not water, is the real issue. The fact that children did not change their address proves only that this population did not receive fluoride from water, not that it has not received fluoride. A nonfluoridated community is only a starting point from which to select out truly nonfluoridated subjects.

Mary Ellen Reitz
Pathologist, St. Vincent
Health Center, Erie, Pa.

CLEAN AIR:
Bush urges broad, costly programs

Hoping to break a 12-year Congressional logjam and seize the political initiative, President Bush has offered sweeping but costly programs to abate acid rain, clear up urban smog, and control cancer-causing emissions from industrial plants and mobile sources. "There is no question but that there will be renewal of the Clean Air Act this year," comments Richard E. Ayres, chairman of the National Clean Air Coalition.

Bush's initiatives were offered only in broad brush strokes, tempering the generally positive responses. For example, House Energy & Commerce Committee chairman John D. Dingell (D.-Mich.) jabs the Reagan Administration's inaction while applauding Bush "for proposing the first comprehensive Clean Air Act revision in this decade." He adds that "the broad outlines appear reasonable, effective, and consistent with the need to promote economic growth and job opportunities." However, Senate majority leader George J. Mitchell (D.-Me.) cautions, "No final judgment can be made until the President submits specific legislation."

Dingell's comments were noted and appreciated by U.S. and Canadian environmental groups who in the past criticized the powerful committee chairman for successfully bottling up reauthorization efforts. Control of acid rain has long been a thorn in U.S.-Canadian relations in general. But Bush's plan received a favorable response from Prime Minister Brian Mulroney who welcomed it as "the most positive step by a U.S. Administration in more than a decade."

Briefly, Bush's clean air proposals would cut coal-fired electric utility emissions, which contribute to acid rain, nearly 50% a year by the year 2000. They would bring two thirds of about 80 smog-choked cities into compliance with the health-based ozone and carbon monoxide standards by 1995. And they would cut cancer-causing air emissions from factories and plants 75 to 90%. Environmental Protection Agency Administrator William K. Reilly estimates that these programs could cost as much as $18 billion a year when they're fully implemented around the turn of the century.

In an ironic twist, U.S. environmentalists find the acid rain proposals the best of the three-part plan, while some industries find them troublesome. National Coal Association president Richard L. Lawson characterizes some of them as "un-

Bush's three-pronged plan for clearing the air

ACID RAIN

Affected sources: 107 coal-fired power plants in 18 states.

Goals: Reduce from 1980 levels sulfur dioxide emissions 10 million tons annually, and nitrogen oxides 2 million tons annually, by year 2000.

Estimated cost: $700 million per year in first phase, $3.8 billion annually in second phase.

Features: Utilities adopting so-called clean coal repowering technologies to receive three-year extension of year 2000 deadline. Affected utilities allowed to trade in pollution rights.

AIR TOXICS

Affected sources: Motor vehicles and about 30 industrial categories, including chemical plants.

Goals: Regulate within 10 years 187 toxic air pollutants from 30 source categories. Prevent catastrophic chemical plant accidents. "Drastically" cut the 2.7 billion tons of toxics emitted annually.

Estimated cost: About $2 billion annually.

Features: Require emitters to use maximum available control technology, measured by EPA standard based on best technology currently available. Sources voluntarily cutting emissions before an enacted standard to receive credits against MACT requirement. After initial phase, EPA to determine if further controls necessary to protect against "unreasonable risk." Chemical safety board established.

URBAN SMOG

Affected sources: Motor vehicles, small sources such as dry cleaners and consumer solvents, and large sources such as petroleum refineries and refueling stations.

Goals: Attain ozone standard in all but three of the most seriously polluted cities by year 2000 by tightening hydrocarbon emission tailpipe standards for automobiles and light duty trucks.

Estimated cost: Up to $4 billion a year when fully implemented.

Features: Expanded vehicle inspection and maintenance programs in areas with serious smog problems. Phasing in of alternative fuels (ethanol, methanol, natural gas) in most serious nonattainment regions. A million clean-fueled vehicles per year to be introduced to these areas by 1997. Eventual regulations allowing automakers to engage in "emissions trading" and petroleum refiners in "fuel pooling."

necessary, unduly harsh, and economically onerous."

Based on the principle that the polluter pays, the plan places the burden of abating acid rain squarely on the shoulders of 107 coal-burning electric utilities in 18 states, centered primarily in the Midwest. These "dirty" utilities would have to cut sulfur dioxide emissions 5 million tons a year by 1995 and another 5 million tons a year by 2000. This is about a 50% reduction in current emissions. The utilities would also have to cut emissions of nitrogen oxides 2 million tons a year by the year 2000, a reduction of about one tenth current emissions.

Utilities would be allowed to achieve reductions by switching to lower sulfur coal, installing flue-gas scrubbers, encouraging conservation among their customers, or adopting innovative technology that permits the burning of fuel without producing pollution. Those utilities that opt for the latter choice would be given an additional three years beyond 2000 to comply.

In addition to the flexible means of achieving reductions, utilities would be allowed to trade pollution rights—buy and sell the right to pollute. Initially trading would only be allowed between plants in the same state or within the same utility system. Later, interstate trading would be permitted.

Under this system, the electric utility customers of the 107 plants can expect to see rate increases of more than 2%, says Energy Secretary James D. Watkins. In addition, consumers will be paying the higher rates without receiving the benefits of the reductions—a sticky point that has derailed past efforts to pass acid rain control legislation.

Although EPA has had no authority to regulate acid rain, it has had the legislative ability to control toxic air pollutants. It has fallen far short of doing so, mainly because it couldn't determine what the law's call for "margin of safety" meant. To date, EPA has regulated only seven toxic air pollutants, but Bush's plan raises the number to be regulated to 187. The President also proposes initiatives to address catastrophic Bhopal-like accidents and to drastically cut the 2.7 billion lb of toxic chemicals now being emitted to the air each year.

Bush proposes controlling such major sources of toxic air pollution as steel mills' coke ovens and chemical plants under a timetable that calls for EPA regulations for controlling 10 of 30 source categories within two years, and all remaining source categories within 10 years. Affected plants and factories will be required to use so-called maximum available control technology (MACT) to cut toxic emissions. This means that EPA will set a standard based on best technology currently available.

EPA is directed to encourage early voluntary compliance by allowing credit against the MACT requirement for those reductions made before the standard is published.

At a press briefing, EPA Administrator Reilly indicated that Bush's legislation will call for a chemical safety board patterned after the National Transportation Safety Board. As envisioned, this board would decrease the likelihood of a Bhopal-like accident by developing and maintaining a data inventory. The board also would be given the power to visit, inspect, analyze, and report on its recommendations following a major release of toxic chemicals.

All of these actions would be part of the first phase. In the next phase, EPA would determine if further controls were necessary to protect the public from "unreasonable risk," and set them if they were.

EPA estimates annual costs of the full air-toxic program at about $2 billion a year.

Chemical industry sources are generally pleased with the program, although they caution that few details are available. The Chemical Manufacturers Association particularly likes the technology-based approach to controlling toxic air pollutants. But CMA's environment division associate director Ann M. Mason says it is still unclear what is meant by best available technology.

The third prong of Bush's proposal addresses the seemingly intractable urban smog problem. He plans to get all but the three most seriously polluted cities into compliance with the ozone (smog) standard by 2000. He would do this by tightening vehicle tailpipe emissions, gasoline volatility requirements, and state inspection and maintenance programs; cutting vehicle evaporative emissions; and regulating toxic emissions from small businesses, consumer products, and hazardous wastes sites.

C&EN staff photo

Bush: calls for chemical safety board

The most novel part of Bush's legislative package calls for the use of vehicles able to operate on such clean fuels as methanol, ethanol, and natural gas. His plan requires a phase-in of such vehicles, with 1 million vehicles a year being sold in the most seriously polluted areas by 1997. Oil and auto industry officials are unhappy with this package.

Lois Ember

MIT industry/research ties questioned

Congress again is scrutinizing the science community's ethics—this time alleged financial conflicts of interest. The academician under fire last week was Massachusetts Institute of Technology president Paul E. Gray, who was grilled by a House panel exploring ties between industry and universities. MIT, the panel said, may be undermining U.S. industry by selling the results of publicly funded research to foreign corporations.

The hearing was held by the Hu-

Investment in Portugal, Plans for Europe 1992 Top CEFIC Agenda

Chief investment target in Portugal's chemical industry is state-owned Quimigal, which will sell all its operations except fertilizers

Patricia L. Layman, C&EN London

Foreign investment in Portugal's chemical industry and trends and problems in preparing for a single internal market in the European Community beginning in 1992 were the focus of discussions at the annual meeting of the European Chemical Industry Federation (CEFIC) held earlier this month in Lisbon.

Referring to the opening of Portugal's chemical industry to foreign investment and ownership, one delegate at the meeting said it's a "come, see, and bid" situation for foreign chemical companies interested in widening their pattern of investment in Western Europe.

Metz: firms lead transnational effort

Chief among the investment targets is Quimigal, the state-owned chemical producer with a variety of interests from commodities such as fibers and fertilizers to specialties, including plastics additives and precious metals. It was created in 1974 from three other chemical companies in an effort to gain some sort of economy of scale. But a host of crises fell upon the company: the two oil crises, collapsed demand, and bureaucratic decision-making incapable of moving as fast as the industry demanded. The result: Since its formation, Quimigal has been one of the major money-losing industries in Portugal.

It still is losing money, concedes Pedro Nunes, a member of the board of directors of the company. But internal restructuring of the company, the decision by the Portuguese government to absorb a hefty share of corporate debt, and the state's restructuring of the company's major business, fertilizers, has improved the company's operations. "There have been no direct financial profits since 1977," says Nunes. "But if you forget the debt interest, Quimigal has been in operating profit since 1986." Moreover, the company, which last year had sales of about $650 million, "will show profit from 1991 onwards," he predicts.

In the meantime, the company is—for all practical purposes—for sale. Only the fertilizers business, an industry of national strategic importance, does not carry a "for sale" sign. All the other operations could be negotiated for, Nunes indicates. A reorganization this February, creating separate new companies from the existing divisions, with the headquarters acting as a holding company, is expected to help any such negotiations.

Chemicals are serious balance of trade deficit for Portugal

$ Millions	1988	1987	1986	1985
Exports	596	586	488	441
Imports	1718	1418	863	633
Sales	$1783	$1702	$1500	$1059

Note: Figures were converted from escudos to U.S. dollars on the basis of $1.00 equals: 1988, 144 escudos; 1987, 141 escudos; 1986, 150 escudos; 1985, 170 escudos. Includes organic and inorganic chemicals, fibers, fertilizers, explosives, resins, and pesticides. **Sources:** European Chemical Industry Federation (CEFIC), International Monetary Fund

Also for sale are sites at the major chemical complexes owned by Quimigal—500,000 square meters of open land and 100,000 sq m of built-up land, which the company is attempting to turn into an industrial park. Existing amenities include road and rail links with Lisbon and the rest of Europe; a deepwater harbor; and water, steam, and electrical supplies—all the infrastructure elements that could appeal to prospective investors, Nunes says.

The Quimigal restructuring follows closely after the Portuguese government's move late last year to invite tender offers for some of the other state-held petrochemical operations. Finnish petrochemicals producer Neste has already snapped up the polyethylene and polypropylene plants being sold by the state in a consortium with two Portuguese companies (C&EN, March 20, page 10). These plants had been owned by Empresa de Polímeros de Sines. Neste would also lease the ethylene feedstock supply.

And when the industry and the state are ready, other nationally owned chemical interests will be privatized, government officials say. "Any investment is welcome," says one official in the department of industry. "Our real priority is creating links between national and international companies—for example, with companies who want joint ventures. We don't want just foreign capital, but know-how and technology."

The Portuguese industry has made significant strides back to health, notes Günter Metz, vice chairman of the board of management at West German chemical producer Hoechst, and current president of CEFIC. In his address to the meeting's general assembly, he offered his congratulations to the Portuguese chemical industry. "I believe," he said, "that the past five years have seen your industry take important strides forward."

Such strides, he says, have been particularly important in helping Portugal's economic and political integration into the European Community. The EC, in fact, was at the heart of Metz's concerns during the assembly. CEFIC, he says, is looking beyond the single internal market of 1992, and has established a task force, CEFIC 2000, to identify issues that will be facing the industry by the turn of the century and ways the federation can address the issues.

Finnish industry proposes environment initiative for Europe

At the Lisbon general assembly of the European Chemical Industry Federation (CEFIC), the Finnish Chemical Industry Federation introduced its "environment initiative," presented to its government in late May, to put together a body to fund environmental protection and cleanup throughout Europe, particularly the East bloc.

The rest of the national representatives from CEFIC clearly were surprised by the initiative, as Gunter Metz, current CEFIC president, admitted during a press conference. And he saw practical problems with the proposal. However, he emphasized, "if there is a possibility, we should use it—the environment is a European problem."

CEFIC was presented the same proposal put forward in May by the board of directors of the Finnish Chemical Industry Federation to the Council of State to create—with extensive international cooperation—a financing system for environmental protection throughout the whole of Europe.

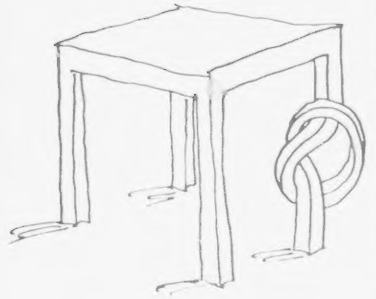
Says the federation's working proposal: "The effectiveness of the results [to reduce the emission of pollutants and the development of technology designed to spare the environments] is diminished by the fact that the situation is not the same throughout Europe. Emissions harmful to the environment are carried by the wind and water irrespective of national boundaries. Not all of the countries have been able to achieve even a moderate minimum level of environmental protection.

"The emissions derived from Eastern European countries represent a particular threat to the future of the state of the environment in the whole of Europe. The socialist countries, with their economic problems, have not been able to invest sufficiently in environmental protection during the past decades.

"The need for environmental protection technology has become increasingly apparent in both discussions at the company level and in the official working groups of the chemical industries of Finland and the socialist countries. It has also become apparent that information about suitable technology is not, in itself, enough. External financing is also required. The problems are so immense that normal commercial financing will hardly suffice.

"Funds directed at environmental protection in the industry of Finland and a number of other European countries will bring about only a marginal improvement in the state of the environment in the whole of Europe if the above-mentioned immense problems are not solved.

"Finland proposes the establishment of a European Environmental Protection Fund, which would finance environmental protection investments in those countries whose economic situation has so far not permitted it. This would provide a solution to the great problems threatening the environment in Europe in the very areas where the problems are most acute."



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Among the issues is centralization of decision-making within the EC. "No sooner have we become accustomed to the challenges of the single market liberalizations, than we are faced with the much more demanding issue of how far we should abandon our ingrained national prerogatives and cede an unprecedented degree of sovereignty to the center," Metz says.

Companies, Metz says, are leading the transnational movement. "Companies are beginning to think in terms of investing in different parts of Europe, when before they contented themselves with investing in different regions of their own country."

However, national governments are the slow partner. "The process of Europeanization is not happening fast enough when it comes to national administrations, specifically in the area of environmental regulation," he warns. The authorities in EC member states "are, in fact, creating chaos in the chemicals sector by burdening us with wildly differing national environmental rules. These different national regulations are making it harder to tackle Europe's environmental problems and are liable to create trade distortions that will lead to fragmentation of the Common Market just at the point when we thought movement was at last in the other direction."

One specific problem is waste management, which—rather than being dealt with on an international basis—is threatened by national controls, or the banning of transfrontier movement of waste. This would pose a threat to the establishment of specialized treatment plants now being proposed to serve the whole European industry. "Given the cost of setting up such facilities, it would be absurd to do so on a national basis," Metz says.

CEFIC is banking in part on its corporate members, who are affiliated via the Assembly of Corporate Associate Members, to help with some gentle lobbying. "The ACAM members are of increasing importance—those companies are European, not national. We need their expertise for our negotiations with the European Commission and the European Parliament," Metz says. □

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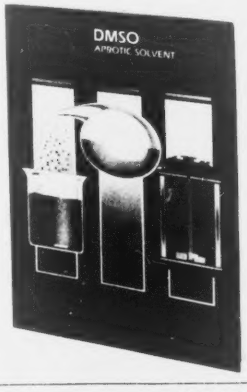

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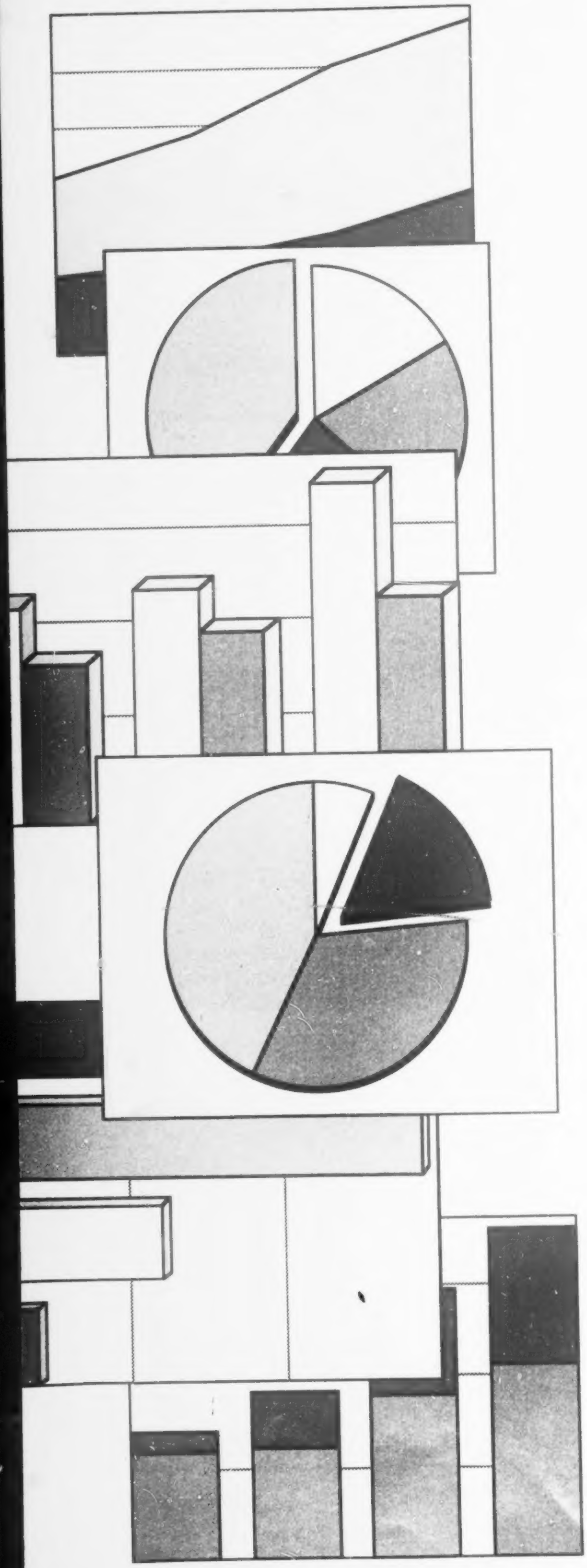


Facts for the chemical industry at a glance

The data in the graphs and tables on the following pages of C&EN's annual Facts & Figures issue clearly show that the business climate of the late 1980s has been remarkably favorable for the chemical industry, not only in the U.S. but worldwide.

Last year, in fact, was by many measures the best in recent memory. With demand vigorous, chemical producers were selling more of their products at higher prices, were operating smoothly and efficiently, and in many cases were earning

1 Production

Output of chemicals in the U.S. in 1988 was 8% higher than the year before. Although production has been rising steadily since the 1982 recession, last year's increase was the biggest since the initial recovery year of 1983. Clearly, the industry's recovery from its early 1980s' slump has had remarkable staying power. As usual, plastics and organic intermediates were the product lines setting the fastest pace. But synthetic rubber also was strong, and an uptrend for fertilizers bolstered some of the inorganic chemicals used in making them. Fiber output was a mixed bag; it was a relatively good year for olefins and polyester but a stagnant one for nylon and acrylics.

Page 38

& Figures

more than ever before. Financially, the industry was trim but sturdy. Funding for new plants and for increased research was on the upswing.

This year promises to bring further expansion. Nevertheless, some clouds are hovering on the horizon. Signs of slackening growth in many major markets in the U.S. are apparent. And with capacity increasing at the same time, the positive trend in selling prices of the past few years is coming under increasing pressure. With a good first half already under its belt, the chemical industry is still confident that 1989 will be another year of progress. But when the statistics for the year are displayed in Facts & Figures next June, they may not have quite the rosy hue that is so evident this year.

2 Finances

Chemical companies' profitability strengthened remarkably during 1988, buoyed by the heady combination of higher demand, strong prices, rising productivity, and generally effective cost control. Because sales are strong, the industry has been hiking its outlays for new plant and equipment; a C&EN survey of major chemical producers indicates that they invested 34% more last year than in 1987. And they plan another big boost in capital spending again this year. Budgets for R&D also are climbing. **Page 51**

3 Employment

Employment in the chemical industry continued to rebound from its low point of late 1986 and early 1987. But the 3% increase last year still kept the total number of people working in the industry well under the level of the early 1980s. And with employment of production workers still relatively low despite rapid growth in output, productivity in the industry has continued to expand and now stands nearly 50% above the level of a decade ago. **Page 67**

4 Markets

Consumers continued to be liberal spenders during 1988, underpinning the overall U.S. economy and fueling demand for chemical products. Some major markets for chemicals, however, were less buoyant last year, suggesting that overall growth for chemicals may soon show signs of slackening. Two important ones are housing construction, which dipped for the second year in 1988, and auto assembly. Demand remained firm, however, from such industries as textiles, paper, and tires. **Page 74**

5 Foreign Trade

With continued weakness in the dollar permitting U.S. chemical producers to price their products competitively in overseas markets, exports of chemicals from the U.S. climbed more than 20% to an impressive all-time high of $32.3 billion. Imports of chemicals rose, too, at about the same rate. But that did not prevent the chemical balance of trade from swelling to a record $12.4 billion, and U.S. exporters managed to win a larger share of the global market for chemicals for the first time since 1985. **Page 76**

6 Foreign Chemical Industries

Business was prosperous for chemical producers throughout the industrialized world last year. As a result, reports from Western Europe, Japan, and Canada all have a similar tone: Output was higher, prices were strong, operating costs were under control, and consequently profitability was much improved. Growth was also apparent elsewhere, including China and several of the other Pacific Rim nations. But it was less robust in the Soviet Union and some of its East European satellites. **Page 79**

Growth maintains a strong pace

Production growth of the U.S. chemical industry was even stronger in 1988 than it was in 1987. Output rose 8% last year, compared with 6% in 1987 and 5% in 1986, making 1988 the sixth straight year of expansion and the year of greatest growth. Chemicals did somewhat better than industry as a whole in 1988; total industrial production was up only 6%.

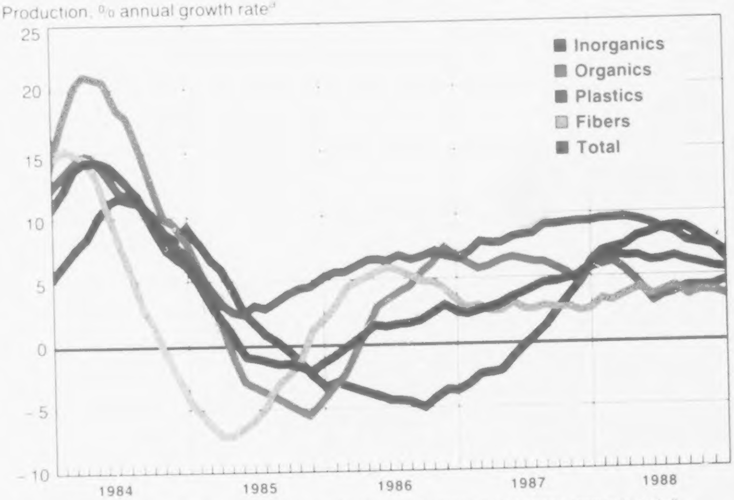
Some of the strongest sectors of the chemical industry were organic chemicals, plastics, drugs, soap and toiletries, agricultural chemicals, and synthetic rubber. Plastics production rose an overall 9%, with epoxy resins up 14%, thermoplastic polyester up 19%, and styrene-acrylonitrile—a relatively small volume resin—leading the way at 17%.

Output of inorganic chemicals, as measured by the Federal Reserve Board's production index, was down slightly in 1988 after recovering somewhat in 1987. Even though industrial gases and inorganic pigments rose moderately, production losses for some major inorganic chemicals pulled the total down.

Output of all fertilizers except concentrated superphosphate rose in 1988, but ammonium nitrate and concentrated superphosphate have experienced an overall decline in the past six years. Consumption of phosphate and potash nutrients also has declined during the past decade.

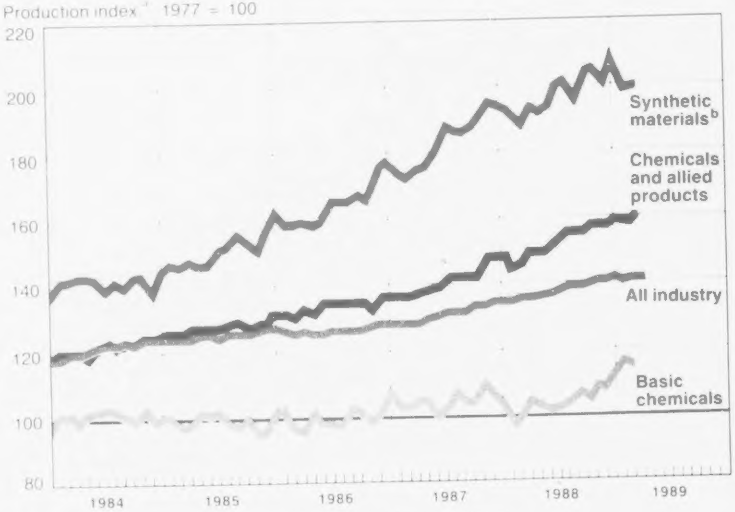
For most minerals used for making chemicals, output was up last year, but for the majority production is still below 1978 levels. Noncellulosic fibers as a whole grew in 1988, although acrylic and nylon output both fell 1%. Even though acetate and rayon production grew slightly, they remain much lower than they were a decade ago. Likewise, synthetic rubber production is also up, as it has been since 1986, but it, too, has experienced an overall decline in the past decade.

All chemical sectors posted further steady growth in 1988



a Average running annual growth rates in production of major plastics, inorganic and organic chemicals, and all chemicals, and in shipments of man-made fibers. **Sources**: International Trade Commission, Bureau of the Census, Society of the Plastics Industry, Textile Economics Bureau

Uptrend continues in chemical production



a Seasonally adjusted. b Includes plastics, synthetic rubber, and man-made fibers. **Source**: Federal Reserve Board

TOP 50 CHEMICALS: Increases in output for past two years well above average for past decade

Rank			Billions of lb		Common units[b]		Average annual growth			
1988	1987[a]		1988	1987	1988	1987	1987–88	1986–87	1983–88	1978–88
1	1	**Sulfuric acid**	85.56	77.50	42,779 tt	38,750 tt	10.4%	5.2%	2.7%	0.3%
2	2	**Nitrogen**	52.10	47.39	719 bcf	654 bcf	9.9	−2.5	5.1	6.3
3	5	**Oxygen**	37.09	32.28	448 bcf	390 bcf	14.9	−2.3	5.3	0.5
4	3	**Ethylene**	36.56	34.99	36,562 mp	34,992 mp	4.5	6.5	5.0	3.5
5	4	**Ammonia**	33.89	32.32	16,946 tt	16,161 tt	4.9	15.4	4.0	−0.1
6	6	**Lime[c]**	32.34	30.36	16,169 tt	15,182 tt	6.5	2.3	1.7	−2.3
7	7	**Sodium hydroxide**	23.97	23.04	11,983 tt	11,518 tt	4.0	7.7	3.2	0.6
8	9	**Phosphoric acid**	23.43	20.95	11,717 tt	10,473 tt	11.9	13.8	3.7	2.0
9	8	**Chlorine**	22.66	21.96	11,329 tt	10,980 tt	3.2	5.2	2.6	0.2
10	10	**Propylene**	19.97	18.53	19,966 mp	18,527 mp	7.8	12.1	7.4	4.4
11	11	**Sodium carbonate[d]**	19.10	17.78	9,550 tt	8,891 tt	7.4	5.4	2.4	1.4
12	13	**Nitric acid**	15.78	14.20	7,889 tt	7,102 tt	11.1	8.2	2.5	−0.1
13	12	**Urea[e]**	15.76	14.88	7,878 tt	7,441 tt	5.9	23.4	5.6	2.3
14	15	**Ammonium nitrate[f]**	14.38	12.83	7,188 tt	6,416 tt	12.0	15.5	2.9	0
15	14	**Ethylene dichloride**	13.65	13.81	13,652 mp	13,805 mp	−1.1	6.7	3.5	2.2
16	16	**Benzene**	11.84	11.67	1,608 mg	1,585 mg	1.5	16.4	5.5	0.8
17	18	**Ethylbenzene**	9.94	9.41	9,936 mp	9,409 mp	5.6	4.3	4.8	1.7
18	20	**Terephthalic acid[g]**	9.60	8.11	9,604 mp	8,110 mp	18.4	5.5	11.3	4.9
19	17	**Carbon dioxide[h]**	9.38	9.86	4,691 tt	4,932 tt	−4.9	1.0	3.7	4.0
20	19	**Vinyl chloride**	9.06	8.23	9,056 mp	8,230 mp	10.0	−2.5	5.7	2.7
21	21	**Styrene**	8.59	8.09	8,588 mp	8,090 mp	6.2	2.6	4.8	1.8
22	22	**Methanol**	7.34	7.29	7,343 mp	7,292 mp	0.7	1.2	−1.7	1.3
23	24	**Formaldehyde[i]**	6.73	6.08	6,730 mp	6,077 mp	10.7	9.5	4.3	0.5
24	23	**Toluene[j]**	6.47	6.73	892 mg	928 mg	−3.9	51.9	2.7	−1.7
25	25	**Xylene**	5.93	5.72	824 mg	795 mg	3.6	27.6	2.6	−0.3
26	28	**Hydrochloric acid**	5.87	4.99	2,933 tt	2,495 tt	17.6	3.4	3.9	0.5
27	27	***p*-Xylene**	5.60	5.15	5,598 mp	5,152 mp	8.7	2.3	6.4	4.8
28	26	**Ethylene oxide**	5.37	5.62	5,365 mp	5,623 mp	−4.6	3.6	−0.6	0.5
29	29	**Ethylene glycol**	4.90	4.52	4,899 mp	4,515 mp	8.5	−5.4	2.1	2.3
30	31	**Cumene**	4.80	4.15	4,800 mp	4,151 mp	15.6	10.8	7.5	3.6
31	32	**Methyl *tert*-butyl ether[k]**	4.68	3.37	4,684 mp	3,372 mp	38.9	−0.1	41.0	na
32	30	**Ammonium sulfate**	4.67	4.37	2,337 tt	2,183 tt	7.1	4.7	3.6	−0.5
33	33	**Phenol[l]**	3.53	3.24	3,528 mp	3,241 mp	8.9	4.0	6.0	2.8
34	36	**Potash[m]**	3.35	2.78	1,520 tmt	1,262 tmt	20.4	5.0	1.2	−3.9
35	35	**Butadiene[n]**	3.19	3.00	3,194 mp	3,002 mp	6.4	15.8	6.3	−1.0
36	34	**Acetic acid**	3.16	3.23	3,164 mp	3,227 mp	−2.0	18.3	2.4	1.3
37	38	**Propylene oxide**	3.11	2.61	3,110 mp	2,608 mp	19.2	5.2	10.8	4.3
38	37	**Carbon black**	2.92	2.72	2,916 mp	2,724 mp	7.0	5.4	3.2	−1.4
39	41	**Aluminum sulfate**	2.59	2.45	1,297 tt	1,223 tt	6.1	0.1	3.3	−0.1
40	39	**Acrylonitrile**	2.58	2.55	2,576 mp	2,551 mp	1.0	16.9	3.7	3.9
41	40	**Vinyl acetate**	2.56	2.51	2,561 mp	2,505 mp	2.2	46.5	5.5	4.2
42	42	**Cyclohexane**	2.32	2.25	2,319 mp	2,250 mp	3.1	8.6	7.0	−0.1
43	43	**Acetone**	2.29	2.08	2,285 mp	2,082 mp	9.8	7.5	4.2	−1.0
44	44	**Titanium dioxide**	2.04	1.90	1,021 tt	952 tt	7.2	2.3	6.2	3.8
45	46	**Sodium sulfate[o]**	1.69	1.61	845 tt	805 tt	5.0	3.9	−0.2	0.4
46	44	**Sodium silicate**	1.64	1.90	821 tt	952 tt	−13.8	21.1	2.4	−0.1
47	47	**Adipic acid**	1.59	1.57	1,588 mp	1,572 mp	1.0	3.3	4.4	−0.2
48	49	**Isopropyl alcohol**	1.42	1.31	1,418 mp	1,313 mp	8.0	0.9	3.2	−2.0
49	48	**Calcium chloride[p]**	1.31	1.55	657 tt	773 tt	−15.0	−0.9	−5.2	−4.4
50	50	**Caprolactam**	1.26	1.16	1,261 mp	1,161 mp	8.6	4.7	5.2	3.2
TOTAL ORGANICS			213.79	201.87			5.9%	9.6%	5.2%	2.4%
TOTAL INORGANICS			395.76	[illegible]			8.5%	4.9%	3.3%	0.8%
GRAND TOTAL			609.55	[illegible]			7.6%	6.5%	4.0%	1.3%

a Revised. **b** **tt** = thousands of tons, **bcf** = billions of cubic feet, **mp** = millions of pounds, **mg** = millions of gallons, **tmt** = thousands of metric tons. **c** Except refractory dolomite. **d** Natural and synthetic. **e** 100% basis. **f** Original solution. **g** Includes both acid and ester without double counting. **h** Liquid and solid only. **i** 37% by weight. **j** All grades. **k** Production data for earlier years unavailable. **l** Synthetic only. **m** K_2O basis. **n** Rubber grade. **o** High and low purity. **p** Solid and liquid. **na** = not available.

PRODUCTION Except for inorganic chemicals, 1988 was a year of healthy expansion

Industrial production indexes, 1977 = 100	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	Annual change 1987-88	Annual change 1978-88
Total index	137.2	129.8	125.1	123.7	121.4	109.2	103.1	111.0	108.6	110.7	106.5	6%	3%
Manufacturing, total	142.8	134.7	129.1	126.4	123.4	110.2	102.2	110.5	108.2	111.5	107.1	6	3
Nondurable manufacturing	143.9	136.8	130.1	124.6	122.3	113.7	105.5	109.7	107.0	108.2	105.5	5	3
Chemicals and products	151.9	140.2	132.0	126.4	121.6	114.0	103.8	112.6	106.4	111.4	106.8	8	4
Chemicals and synthetic materials	145.2	135.6	123.8	118.6	114.7	109.1	95.4	109.4	99.4	113.7	106.2	7	3
Basic chemicals	103.9	104.9	98.9	100.0	100.6	95.0	90.6	104.3	107.2	110.1	110.7	−1	−1
Alkalies and chlorine	102.2	103.4	97.5	97.1	97.8	91.5	83.3	96.1	104.1	113.6	101.7	−1	0
Industrial gases	158.0	150.3	128.3	127.0	123.6	114.0	103.9	115.4	105.0	107.2	98.7	5	5
Inorganic pigments	103.9	100.5	99.6	96.2	95.4	91.5	81.7	99.0	97.6	100.8	103.5	3	0
Inorganic chemicals, nec	95.2	98.2	94.1	96.5	97.9	92.9	90.9	104.6	109.4	111.1	115.3	−3	−2
Industrial organic chemicals	134.9	122.9	112.7	109.2	106.2	104.0	90.3	105.5	89.1	108.1	104.5	10	3
Synthetic materials	195.1	181.7	162.6	149.4	140.3	129.0	108.0	120.2	110.1	125.8	112.2	7	6
Plastics materials	275.3	252.5	220.0	197.4	179.8	158.7	129.9	136.1	122.1	132.6	115.6	9	9
Synthetic rubber	100.2	92.7	96.5	96.8	107.6	98.3	86.8	91.2	93.0	112.1	99.0	8	0
Man-made fibers	106.2	104.3	98.5	95.3	94.1	95.4	82.9	104.6	97.3	119.4	110.2	2	0
Chemical products	167.0	152.1	147.5	139.3	132.4	123.2	114.7	116.5	113.7	110.1	106.7	10	5
Drugs and medicines	151.5	138.3	134.8	126.4	121.7	118.8	114.2	112.0	112.9	107.5	105.1	10	4
Soap and toiletries	210.2	188.9	182.9	168.1	155.9	139.9	125.4	129.6	121.5	115.0	106.6	11	7
Paints	107.0	100.5	100.1	98.6	92.9	90.1	83.5	86.7	89.7	95.0	104.7	6	0
Agricultural chemicals	100.8	92.4	85.7	96.1	98.2	86.9	90.2	109.2	107.3	103.9	97.5	9	0
Petroleum products	96.0	93.5	92.6	86.9	87.4	84.0	84.2	89.4	94.0	101.7	102.5	3	−1
Rubber and plastics products	174.4	163.6	151.4	146.1	143.5	124.3	110.2	116.4	107.8	114.9	107.5	7	5

nec = not elsewhere classified. **Source:** Federal Reserve Board

MINERALS Despite recent gains, output for most chemical minerals is still below 1978 level

Thousands of tons	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	Annual change 1987-88	Annual change 1978-88
Bromine, sold or used[a]	180	168	155	160	193	185	200	189	189	249	223	7%	−2%
Calcium chloride, production[b,c]	657[d]	773[d]	780	940	1,036	912	853	917	811	981	1,031	−15	−4
Iodine, consumption[e,f]	na	na	na	na	3.8	4.1	3.4	4.4	4.4	4.4	4.0	na	na
Imports[f]	1.4[d]	1.3	1.6	2.7	2.6	3.1	2.3	3.0	3.1	3.1	3.4	8	−8
Lime, sold or used[g]	16,700	15,733	14,474	15,690	15,922	14,867	14,075	18,890	19,037	20,983	20,484	6	−2
Lithium, consumption[e,h]	3.1[d]	2.7	2.6	2.5	3.2	2.2	2.0	3.2	3.0	3.2	3.4	15	−1
Phosphate rock													
Marketable production	50,000	45,145	44,445	56,035	54,230	46,928	41,241	59,110	59,362	56,891	55,156	11	−1
Exports	9,235	9,319	8,651	10,071	12,707	13,239	10,849	11,458	15,737	15,827	14,187	−1	−4
Potash (K_2O equivalent)[i]													
Production	1,680[d]	1,391	1,325	1,429	1,724	1,575	1,967	2,377	2,468	2,453	2,484	21	−4
Imports[j]	4,500[d]	4,490	4,643	5,063	5,323	4,894	4,253	5,287	5,481	5,693	5,189	0	−1
Apparent consumption	5,429[d]	5,609	5,338	5,893	6,638	6,231	5,647	6,849	6,999	7,626	6,840	−3	−2
Salt, total sold or used[k]	37,500[d]	36,493	36,663	40,067	39,225	34,573	37,894	38,915	40,396	45,820	42,896	3	−1
Evaporated[l]	6,800[d]	5,700	6,233	6,010	5,492	5,532	5,305	6,209	6,358	6,248	5,872	19	1
Rock[l]	12,400[d]	12,100	13,565	14,023	13,337	12,446	12,884	11,871	11,806	14,891	14,688	2	−2
Salt in brine[l]	18,400[d]	17,850	16,865	20,034	20,397	16,595	19,705	20,835	22,231	24,681	22,336	3	−2
Sodium carbonate, production[c]	9,550	8,891	8,438	8,511	8,511	8,467	7,819	8,281	8,275	8,253	8,290	7	1
Sulfur, production[m]	11,845	11,616	12,221	12,797	11,742	10,240	10,788	13,388	13,080	13,339	12,318	2	0
Apparent consumption[n]	14,012	12,481	11,669	13,192	13,976	12,112	11,088	14,093	15,056	15,145	13,889	12	0
Frasch, production	3,499	3,530	4,457	5,524	4,622	3,530	4,641	6,997	7,044	7,007	6,226	−1	−6
Recovered elemental, production	7,103	6,791	6,411	5,857	5,747	5,462	4,855	4,695	4,490	4,486	4,478	5	5
Other, production	1,243	1,296	1,354	1,416	1,372	1,249	1,293	1,695	1,547	1,845	1,615	−4	−3

a Elemental bromine sold as such or used in preparation of bromine compounds by primary producers. **b** 75% $CaCl_2$ equivalent. **c** Natural and synthetic. **d** Preliminary figure. **e** Estimated apparent consumption. **f** Crude elemental iodine. **g** Includes Puerto Rican production. **h** Lithium content basis. **i** Includes muriate and sulfate of potash, potassium magnesium sulfate, and parent salts; excludes other chemical compounds containing potassium. **j** Includes nitrate of potash. **k** Total obtained by all recovery methods that was sold or used by domestic producers (figures differ slightly from U.S. production figures); figures for 1978–81 include Puerto Rican production. **l** Sold or used as such. **m** Sulfur content basis. **n** Calculated from shipments plus imports minus exports (sulfur content basis). **na** = not available. **Source:** Bureau of Mines

1 Production by the U.S. Chemical Industry

ORGANIC CHEMICALS: 1987's strong rise was often repeated in 1988

Millions of lb unless otherwise noted	Production											Annual change	
	1988[a]	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1987–88	1978–88
Acetic acid, synthetic	3,164	3,246	2,728	2,897	2,619	2,807	2,748	2,705	2,977	3,265	2,776	−3%	1%
Acetone	2,285	1,846	1,910	1,788	1,862	1,859	1,694	2,144	2,076	2,653	2,519	24	−1
Acrylonitrile	2,576	2,452	2,182	2,349	2,219	2,146	2,035	1,997	1,830	2,018	1,752	5	4
Aniline	1,032	829	824	716	786	663	557	634	659	690	606	24	5
Benzene, mg[b,c]	1,608	1,585	1,362	1,283	1,318	1,232	1,052	1,308	1,534	1,612	1,435	1	1
Bisphenol A	1,077	1,000	956	949	762	643	480	555	530	576	471	8	9
1,3-Butadiene[d]	3,194	2,931	2,546	2,340	2,452	2,353	1,915	2,986	2,799	3,583	3,515	9	−1
1-Butanol	1,194	1,155	881	716	908	833	730	809	790	766	756	3	5
Caprolactam	1,261	1,156	1,109	1,089	1,027	977	793	928	905[e]	945	919	9	3
Carbon tetrachloride	759	672	627	646	713	573	587	726	710	714	737	13	0
Chloroform	524	462	422	275	405	362	299	405	273	356	349	13	4
Cumene	4,800	4,105	3,745	2,627	3,754	3,345	2,743	3,309	3,459	3,917	3,380	17	4
Cyclohexane	2,319	2,276	2,070	1,657	1,994	1,656	1,275	1,820	1,964	2,425	2,332	2	0
Dioctyl phthalate	334	343	296	275	301	300	266	304	353	336	409	−3	−2
Dodecylbenzene[e]	na	na	851	547	561	545	509	535	563[f]	627	526	na	na
Ethanol, synthetic	na	574	529	649	1,060	1,077	1,023	1,317	1,451	1,408	1,267	na	na
Ethanolamines[g]	611	627	543	537	504	468	416	429	376	420	362	−3	5
Ethylbenzene	9,936	9,346	9,020	7,386	7,562	7,876	6,656	7,813	7,642	8,448	8,385	6	2
Ethyl chloride	152	155	164	171	290	282	339	324	396	582	540	−2	−12
Ethylene	36,562	34,951	32,859	29,847	31,383	28,680	24,501	29,418	28,667	29,904	25,955	5	3
Ethylene dichloride	13,652	12,197	12,940	12,101	10,710	11,506	7,619	9,974	11,108	11,794	11,001	12	2
Ethylene glycol	4,899	5,183	4,771	4,178	4,823	4,425	4,309	4,143	4,386	4,729	3,904	−5	2
Ethylene oxide	5,365	4,785	5,430	5,430	5,699	5,534	4,987	4,937	5,220	5,665	5,012	12	1
2-Ethylhexanol	731	662	571	536	541	387	325	389	367	318	420	10	6
Formaldehyde, 37%[h]	6,730	5,733	5,549	5,606	5,815	5,465	4,817	5,721	5,555	5,971	6,381	17	1
Isopropyl alcohol	1,418	1,371	1,301	1,235	1,394	1,209	1,380	1,669	1,836	1,900	1,730	3	−2
Maleic anhydride	429	382	359	394	359	299	260	293	304	323	341	12	2
Methanol, synthetic	7,343	7,537	7,205	5,003	8,186	7,982	7,555	8,577	7,153	7,367	6,443	−3	1
Methyl chloride	428	373	605	410	482	409	366	405	362	463	454	15	−1
Methyl ethyl ketone	506	672	600	537	543	531	468	614	692	716	644	−25	−2
Methyl methacrylate	1,098	1,029	943	858	917	844	721	592	564	633	570	7	7
Methylchloroform	724	694	652	869	675	586	595	611	587	656	661	4	1
Methylene chloride	504	516	566	467	607	584	532	891	780	931	na	−2	na
Perchloroethylene	495	473	414	678	573	547	585	691	765	773	725	5	−4
Phenol, synthetic[i]	3,528	3,351	3,115	2,841	2,889	2,638	2,023	2,578	2,568	2,981	2,682	5	3
Phthalic anhydride	1,141	1,035	863	820	870	838	684	870	818	1,013	978	10	2
Propylene[j]	19,966	19,019	16,522	14,887	15,559	13,959	12,535	13,482	13,676	14,198	13,014	5	4
Propylene glycol	930	747	573	500	462	484	400	473	488	610	547	24	5
Styrene, monomer	8,588	8,014	7,888	7,622	7,709	6,802	5,942	6,679	6,856	7,484	7,186	7	2
Terephthalic acid, dimethyl ester[k]	9,604	7,601	6,257	6,490	5,912	5,626	4,843	6,235	6,054	6,159	5,954	26	5
Toluene, mg[b,l]	892	928	611	698	728	780	714	852	1,010	1,001	1,046	−4	−2
Vinyl acetate	2,561	1,813	1,710	2,112	2,024	1,963	1,876	1,936	1,922	1,982	1,692	41	4
Vinyl chloride	9,056	8,402	8,439	9,463	6,084	6,875	4,902	6,874	6,466	6,389	6,941	8	3
***o*-Xylene**	945	940	788	675	688	781	802	918	995	1,082	1,013	1	−1
***p*-Xylene**	5,598	5,155	5,035	4,779	4,264	4,114	3,391	4,532	4,238	4,650	3,516	9	5

Note: mg = millions of gallons. **a** Preliminary. **b** Tar distillers and coke-oven operators not included. **c** Specification grades. **d** Rubber grade. **e** Includes straight-chain dodecylbenzene, tridecylbenzene, and other straight-chain alkylbenzenes. **f** Preliminary figure, final figure not available. **g** Mono-, di-, and triethanolamines. **h** By weight. **i** Does not include data for coke ovens and gas-retort ovens. **j** All grades. **k** Includes both acid and dimethyl ester (DMT), without double counting. **l** High-purity toluene, includes material used in blending motor fuel. **na** = not available. **Source:** International Trade Commission

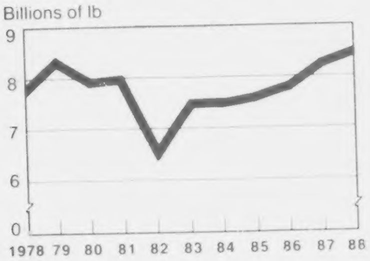
1 Production by the U.S. Chemical Industry

INORGANICS: For many products, output is little changed from 10 years ago

Thousands of tons unless otherwise noted	Production 1988[a]	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	Annual change 1987-88	1978-88
Aluminum sulfate[b]	1,299	1,264	1,222	1,268	1,129	1,119	1,154	1,294	1,286	1,315	1,309	3%	0%
Ammonia, 100%[c,d]	16,937	16,095	14,474	17,319	16,692	14,072	15,801	19,044	19,653	18,634	17,119	5	0
Ammonium nitrate, 100%[e]	7,186	6,547	6,089	6,776	7,146	6,240	7,091	8,861	9,128	8,293	7,210	10	0
Ammonium sulfate,[d,f] 100%	2,337	2,189	2,080	2,093	2,067	1,956	1,768	2,185	2,136	2,363	2,449	7	0
Chlorine gas[g]	11,330	11,019	10,436	10,402	10,700	9,960	9,176	10,763	11,421	12,291	11,052	3	0
Hydrochloric acid, 100%[h]	2,834	2,869	2,413	2,807	2,732	2,468	2,450	2,574	2,888	3,090	2,793	−1	0
Hydrogen, bcf, 100%[i,j]	143	149	142	121	109	103	88	105	107	106	90	−4	5
Nitric acid, 100%[k]	7,887	7,225	6,734	7,631	7,726	6,768	7,390	9,093	9,231	8,916	7,934	9	0
Nitrogen gas, bcf, 100%[i,j]	719	676	617	665	661	560	483	490	479	427	379	6	7
Oxygen, bcf, 100%[i,j]	448	403	347	393	375	346	349	431	431	456	430	11	0
Phosphoric acid, 100% P_2O_5	11,729	10,685	9,578	10,518	11,370	9,767	8,253	9,958	10,848	10,318	9,637	10	2
Phosphorus[m]	352	344	364	359	386	366	361	426	432	460	441	2	−2
Sodium chlorate, 100%	277	289	267	259	295	323	291	297	312	269	265	−4	0
Sodium hydroxide, 100%	11,985	11,486	10,691	10,811	10,914	10,039	9,385	10,621	11,625	12,759	11,309	4	1
Sodium phosphate[n]	555	586	617	625	675	669	651	696	727	757	739	−5	−3
Sodium silicate[o]	813	952	791	737	685	710	664	771	805	813	829	−15	0
Sodium sulfate, 100%[p]	788	813	837	1,203	901	914	864	1,111	1,140	1,121	1,174	−3	−4
Sulfuric acid, 100%[q]	42,775	39,235	35,759	39,651	41,802	36,583	33,233	40,742	44,158	43,204	41,314	9	0
Titanium dioxide, 100%[r]	1,022	968	931	860	835	760	660	761	727	742	701	6	4
Urea	7,878	7,433	6,264	6,678	7,433	6,137	6,470	8,062	7,830	7,000	6,273	6	2

Note: bcf = billions of cubic feet **a** Preliminary **b** Commercial, 17% Al_2O_3, includes municipalities **c** Synthetic anhydrous **d** Excludes by-product ammonia liquor and ammonium sulfate **e** Original solution **f** Synthetic and noncoke by-product **g** Includes quantities liquefied for use, storage, or shipment **h** Includes anhydrous hydrochloric acid production **i** High- and low-purity gas **j** Liquid and gas; excludes amounts vented and used as fuel, and amounts produced in petroleum refineries for captive use **k** Includes unspecified amounts of nitric acid produced but not withdrawn from the system **l** Excludes amounts produced and consumed in making synthetic ammonia or ammonia derivatives **m** Elemental, white (yellow), and red **n** Tripolyphosphate (100% $Na_5P_3O_{10}$) **o** Soluble silicate glass (water glass), solid and liquid (anhydrous); excludes amounts produced and consumed in making meta-, ortho-, and sesquisilicates **p** Anhydrous, high and low purity, and Glauber's salt **q** Gross (new and fortified) **r** Composite and pure **Sources:** Department of Commerce, International Trade Commission

Man-made noncellulosic fibers output



MAN-MADE FIBERS: Output of polyolefins continues to set growth pace

Millions of lb	Production 1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	Annual change 1987-88	1978-88
NONCELLULOSIC FIBERS													
Acrylic[a]	588	592	616	631	671	671	624	691	779	761	726	−1%	−2%
Nylon[b]	2669	2689	2514	2343	2412	2419	1927	2332	2358	2,720	2550	−1	0
Olefins[c]	1568	1494	1393	1249	997	906	723	785	748	759	692	5	9
Polyester	3681	3541	3305	3341	3392	3544	3196	4176	3989	4,178	3800	4	0
CELLULOSIC FIBERS													
Acetate[d]	614	605	619	558	199	229	196	261	316	324	308	1	−4
Rayon					421	401	388	509	490	606	597		
GLASS FIBER	na	na	na	na	1394	1168	899	1,041	867	1,014	923	na	na
TOTAL[e]	**9120**	**8921**	**8447**	**8122**	**9486**	**9336**	**7926**	**9795**	**9547**	**10,362**	**9596**	**2%**	**nc**

a Includes modacrylic **b** Excludes aramid in 1983-87 **c** Includes olefin yarn and monofilaments and olefin and vinyon staple, tow, and fiberfill **d** Includes diacetate and triacetate; excludes production for cigarette filters **e** Totals for 1985, 1986, 1987, and 1988 exclude glass fiber na = not available nc = not comparable **Source:** Textile Economics Bureau

SYNTHETIC RUBBER: Good growth in output for all types last year

Thousands of metric tons	Production 1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	Annual change 1987–88	1978–88
Styrene-butadiene rubber	900	850	792	735	958	904	876	1032	1074	1378	1395	6%	−4%
Polybutadiene	407	371	336	330	359	333	288	342	311	397	378	10	1
Nitrile	76	69	59	53	67	55	45	66	63	75	73	10	0
Ethylene-propylene	263	254	230	215	215	175	123	178	144	175	174	4	4
Other[a]	679	638	596	505	556	468	498	404	423	509	453	6	4
TOTAL	**2325**	**2182**	**2013**	**1838**	**2155**	**1935**	**1830**	**2022**	**2015**	**2534**	**2473**	7%	−1%

a Includes butyl, polychloroprene, polyisoprene, silicone, and other synthetic elastomers. Some values are estimated. **Source:** Rubber Manufacturers Association

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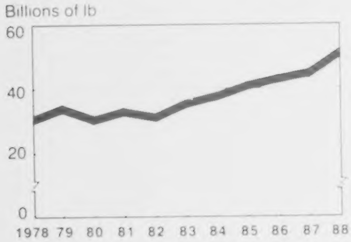
Plastics production

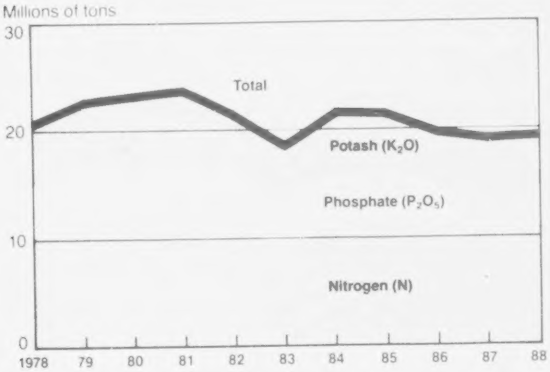


PLASTICS: Production of major resins made healthy gains in 1988

Millions of lb[a]	Production 1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	Annual change 1987–88	1978–88
THERMOSETTING RESINS													
Epoxy[b]	495	433	398	385	406	334	286	336	315	361	299	14%	4%
Polyester[c]	1,404	1,367	1,271	1,223	1,232	1,084	865	997	947	1,147	1,209	3	1
Urea	1,425	1,382	1,271	1,210	1,199	1,172	998	1,165	1,165	1,367	1,122	3	2
Melamine	207	212	173	192	210	180	158	179	167	200	202	−2	0
Phenolic[d]	3,066[e]	2,869[e]	2,735[e]	2,621[e]	2,502[e]	2,477[e]	2,006[e]	2,333[e]	1,499	1,781	1,617	7	nc
TOTAL	**6,597**	**6,263**	**5,848**	**5,631**	**5,549**	**5,247**	**4,313**	**5,010**	**4,093**	**4,856**	**4,449**	5	nc
THERMOPLASTIC RESINS													
Polyethylene													
Low density[f]	10,398	9,599	8,903	8,889	8,413	8,041	7,503	7,693	7,291	7,793	7,111	8	3
High density[g]	8,399	7,995	7,182	6,671	6,085	5,689	4,928	4,695	4,405	5,010	4,201	5	7
Polypropylene	7,272	6,647	5,812	5,139	4,940	4,433	3,477	3,955	3,648	3,841	3,074	9	8
Styrene-acrylonitrile	148	126	92	87	99	93	91	107	111	124	120	17	0
Polystyrene	5,130	4,780	4,470	4,054	3,838	3,570	3,191	3,621	3,521	4,005	3,823	7	2
Acrylonitrile-butadiene-styrene and other styrene polymers[h]	2,420	2,254	2,196	2,036	2,127	1,889	1,380	1,745	1,705	2,107	2,012	7	1
Polyamide, nylon type	566	507	465	399	396	321	228	312	274	327	275	12	6
Polyvinyl chloride and copolymers	8,350	7,971	7,256	6,772	6,760	6,067	5,326	5,707	5,470	6,119	5,723	5	3
Thermoplastic polyester	1,652	1,394	1,175	965	899	778	648	609	na	na	na	19	na
Other vinyl resins[i]	220	212	195	190	187	186	177	208	196	220	197	4	1
TOTAL	**44,555**	**41,485**	**37,746**	**35,202**	**33,744**	**31,067**	**26,949**	**28,652**	**26,621**	**29,546**	**26,536**	7%	5%

Note: Totals are for those products listed and exclude some small-volume plastics. **a** Dry-weight basis unless otherwise specified. **b** Unmodified. **c** Unsaturated. **d** Includes other tar acid resins. **e** Gross-weight basis. **f** Density 0.940 and below. **g** Density above 0.940. **h** Includes styrene-butadiene copolymers and other styrene-based polymers. **i** Includes polyvinyl butyral, polyvinyl formal, and polyvinylidene-chloride. **na** = not available. **nc** = not comparable. **Source:** Society of the Plastics Industry

Fertilizer consumption



Note: Years ending June 30 **Sources:** Department of Agriculture, Fertilizer Institute

FERTILIZERS: Nutrient consumption rose slightly during 1988 crop year

Thousands of tons	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	Annual change 1987–88	Annual change 1978–88
Nitrogen (N)	10,475	10,349	10,424	11,493	11,092	9,127	10,983	11,924	11,407	10,742	9,965	1%	1%
Phosphates (P_2O_5)	4,112	4,013	4,178	4,658	4,901	4,138	4,814	5,434	5,432	5,606	5,096	2	−2
Potash (K_2O)	4,943	4,852	5,053	5,553	5,797	4,831	5,631	6,320	6,245	6,245	5,526	2	−1
Total	**19,530**	**19,214**	**19,655**	**21,704**	**21,790**	**18,096**	**21,428**	**23,678**	**23,083**	**22,565**	**20,587**	**2%**	**−1%**

Note: Years end June 30 **Sources:** Department of Agriculture, Fertilizer Institute

FERTILIZER PRODUCTION Output of most products was substantially higher during 1988

Thousands of tons	1988	1987	1986	1985	1984	1983	Annual change 1978–88	Annual change 1983–88
NITROGEN PRODUCTS								
Ammonia	14,136	13,357	12,565	16,594	16,613	13,361	6%	1%
Ammonium nitrate	2,765	2,472	2,250	3,175	3,365	3,232	12	−3
Ammonium sulfate	2,260	2,153	2,058	2,343	2,078	1,969	5	3
Urea	4,501	4,253	3,564	3,975	4,889	4,112	6	2
Nitrogen solutions	6,999	5,988	5,945	7,928	7,999	6,385	17	2
PHOSPHATE PRODUCTS								
Diammonium phosphate	11,575	9,537	7,492	10,800	12,358	10,264	21	2
Monoammonium phosphate	1,818	1,679	1,416	1,641	1,654	1,423	8	5
Concentrated superphosphate	2,032	2,049	2,127	2,570	2,404	2,684	−1	−5
Phosphate rock	42,220	39,330	36,227	49,348	47,465	40,664	7	1
Phosphoric acid (P_2O_5)	10,234	8,903	8,085	9,837	10,899	9,182	15	2
POTASH PRODUCTS								
Potassium chloride	2,243	1,810	1,715	1,713	2,168	1,928	24	3

Note: Figures are based on Fertilizer Institute surveys and may not represent the entire industry. **Source:** Fertilizer Institute

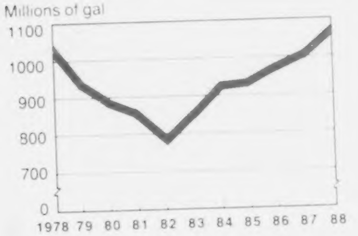
1 Production by the U.S. Chemical Industry

PESTICIDES: Overall production down sharply in 1987, despite increase for insecticides

Millions of lb	Production											Annual change	
	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1986-87	1977-87
Herbicides[a]	556	725	756	716	604	623	839	806	657	664	674	−23%	−2%
Insecticides[b]	379	342	370	350	306	379	448	506	617	605	570	11	−4
Fungicides	105	113	109	123	106	111	143	156	155	148	143	−7	−3
TOTAL	**1040**	**1180**	**1235**	**1189**	**1017**	**1113**	**1430**	**1468**	**1429**	**1416**	**1388**	−12%	−3%

a Includes plant growth regulators. b Includes rodenticides, soil conditioners, and fumigants. **Source:** International Trade Commission

Paints and coatings shipments



COATINGS: All categories move to record levels for decade

Millions of gal	Shipments											Annual change	
	1988[a]	1987[a]	1986	1985	1984	1983	1982	1981	1980	1979	1978	1987-88	1978-86
Architectural	532	510	501	477	457	433	374	417	439	472	na	4%	na
Product[b]	393	360	350	317	336	294	280	312	316	351	na	9	na
Special purpose	162	133	136	145	145	130	129	129	135	116	na	22	na
TOTAL	**1086**	**1004**	**987**	**939**	**938**	**857**	**783**	**858**	**890**	**939**	**1033**	8%	1%

a Preliminary. b For original equipment manufacturers. na = not available. **Source:** Department of Commerce

AEROSOLS: Strong volume gains for personal and automotive products in 1988

Millions of units	Production											Annual change	
	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1987-88	1978-88
Personal products	1100	964	952	879	832	747	628	645	637	772	729	14%	4%
Household products	650	640	635	630	603	586	556	575	580	653	628	2	0
Automotive and industrial products	440	379	375	342	337	303	286	302	310	300	275	16	5
Paints and finishes	331	307	297	290	307	300	295	313	310	302	309	8	1
Insect sprays	190	190	193	190	184	180	166	173	150	199	132	0	4
Food products	157	140	136	140	138	132	131	145	130	141	143	12	1
Animal products	8	22	22	15	16	19	19	14	15	18	15	−64	−6
Miscellaneous	31	80	18	23	15	15	13	28	30	14	a	−61	na
TOTAL	**2907**	**2722**	**2628**	**2509**	**2432**	**2282**	**2094**	**2195**	**2162**	**2399**	**2231**	7%	3%

a Not shown separately. na = not available. **Source:** Chemical Specialties Manufacturers Association

CHLOROFLUOROCARBONS: Production soared last year

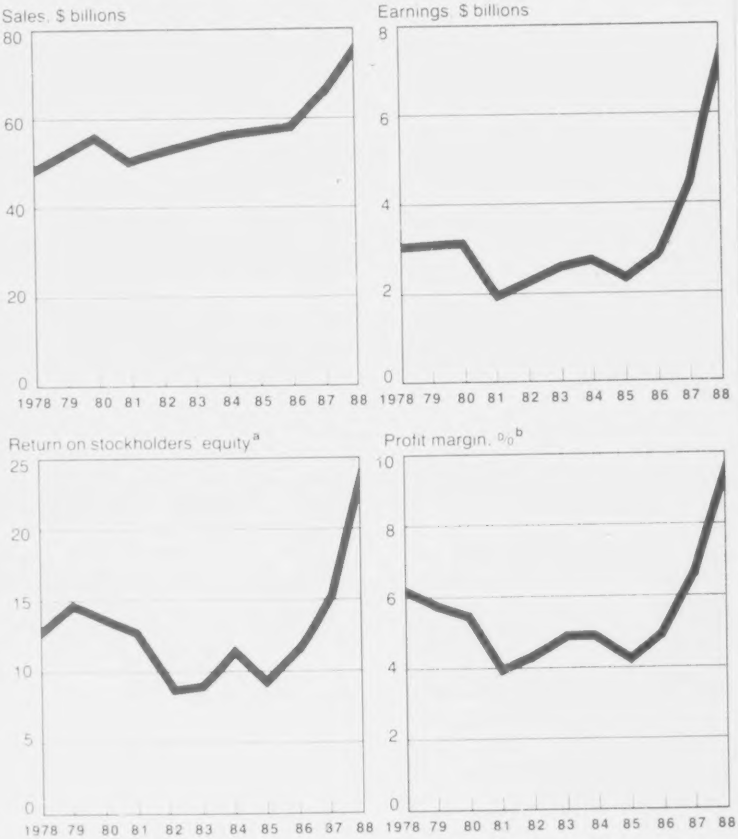
Millions of lb	Production											Annual change	
	1988[a]	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1987-88	1978-88
Chlorodifluoromethane (F-22)	324	275	271	235	254	236	174	252	227	211	206	18%	5%
Dichlorodifluoromethane (F-12)	384	335	322	302	337	290	258	325	295	294	327	15	2
Trichlorofluoromethane (F-11)	223	198	202	176	185	215	140	163	158	167	194	13	1
All other fluorinated hydrocarbons[b]	na	354	344	306	337	279	na	na	na	202	189	na	na
TOTAL	na	**1162**	**1139**	**1019**	**1113**	**1020**	**na**	**na**	**na**	**874**	**916**	**na**	**na**

a Preliminary. b Includes other fluorohalogenated hydrocarbons. na = not available. **Source:** International Trade Commission

2 Finances of the U.S. Chemical Industry

Another good year for chemical firms

As earnings continue to soar, profitability has strengthened markedly in the chemical industry



Note: Based on data for 30 major chemical companies. a After-tax earnings as a percentage of year-end stockholders' equity. b After-tax earnings as a percentage of sales.

If 1987 was a good year for the chemical industry, 1988 was even better. Company executives have every reason to be pleased with what happened at their firms.

Last year, to be sure, simply continued the economic momentum that has built up for the chemical industry since mid-decade in terms of almost all measures of performance. The improved results were spurred by many factors. Demand for chemical products soared once again, rising 13% from 1987. Prices, up 9%, rose to the point that many observers began to worry about substitution of other materials for their products—a fear that seems to have been unfounded thus far. Capacity utilization continued to climb, reaching an 87.3% level in 1988, in spite of some new plants and plant expansions coming on stream.

Export demand was the source of another fear that failed to materialize—that export demand was reaching its limit by the end of 1987 and would slow during last year. But government figures show that exports of chemicals and allied products increased about 22% last year compared with a gain of about 16% the previous year. Unfortunately, imports rose about as much, slowing the growth of the chemical trade surplus in 1988 from the more than 30% increase of the year before.

However, overall, the result was increasing sales and profits for chemical companies and profitability that has hit levels not seen in many years.

For the 30 chemical companies regularly tracked by C&EN, sales in 1988 increased 16%, following a 13% rise the year before. And in spite of an apparent slowing of the surge at year's end, after-tax earnings from continuing operations for the 30 companies rose 67%, compared with a 52% increase in 1987.

Because of continued efficiencies in chemical operations, plus the fact that prices for chemicals were rising faster than raw material costs in many cases, profitability soared for chemical firms. Average profit margin for the 30 companies jumped to 9.8% in 1988 from 6.8% in 1987 and 5.0% in 1986. Return on equity did even better, rising to a hardly believable average of 24.0% from 15.3% in 1987. In 1986, the average return on equity was 11.7%.

Overall, practically all measures of financial performance for chemical companies improved last year as firms reaped the benefits of a buoyant national business climate, low raw material costs, and low inflation overall relative to their own selling prices.

At the same time, many companies are still reaping the benefits in improved efficiency that stem from the drastic corporate restructuring and cost-cutting measures they undertook during the mid-1980s.

TOP 100 CHEMICAL PRODUCERS: Some major new entrants make the list for 1988

Rank 1988	Rank 1987		Chemical sales 1988 ($ millions)	Change from 1987	Chemical sales as % of total sales	Industry classification	Chemical operating profits[a] ($ millions)	Change from 1987	Chemical operating profits as % of total	Operating profit margin[b]	Identifiable chemical assets ($ millions)	Chemical assets as % of total assets	Operating return on chemical assets[c]
1	1	**Du Pont**	$14,717	12.8%	44.7%	Diversified	$2612	12.9%	61.3%	17.7%	$10,290	38.3%	25.4%
2	2	**Dow Chemical**	12,128	11.8	72.7	Basic chemicals	3655	89.4	88.0	30.1	10,792	66.5	33.9
3	3	**Exxon**	9,990	39.2	11.4	Petroleum	1863	71.4	21.2	18.6	6,731	9.1	27.7
4	4	**Union Carbide**	7,601[d]	23.1	91.3	Basic chemicals	1542	76.8	96.0	20.3	6,897	88.3	22.4
5	5	**Monsanto**	5,535	7.2	66.7	Basic chemicals	910	18.8	95.3	16.4	4,144	49.0	22.0
6	6	**Hoechst Celanese**	5,369	25.3	94.5	Basic chemicals	563	26.8	102.4	10.5	na	na	na
7	10	**Occidental Petroleum**	4,673	56.2	23.4	Petroleum	1050	163.8	191.6	22.5	5,258	25.3	20.0
8	7	**BASF**	4,536	18.9	88.0	Basic chemicals	na	na	na	na	na	na	na
9	9	**Amoco**	4,352	24.6	18.2	Petroleum	1022	45.2	28.1	23.5	2,920	9.9	35.0
10	11	**Mobil**	4,280	46.3	7.9	Petroleum	851	96.5	19.4	19.9	2,802	7.7	30.4
11	8	**Shell Oil**	4,006	12.0	19.0	Petroleum	746	24.3	34.1	18.6	3,822	14.1	19.5
12	14	**General Electric**	3,539[d]	28.6	7.1	Diversified	733	44.6	12.3	20.7	7,130	6.4	10.3
13	16	**Chevron**	3,204	23.6	11.6	Petroleum	616	55.2	19.0	19.2	2,101	6.7	29.3
14	13	**W. R. Grace**	3,131	12.1	54.1	Specialty chemicals	388	8.7	65.2	12.4	2,204	48.4	17.6
15	15	**Eastman Kodak**	3,033	16.7	17.8	Photo equipment	628	61.9	21.4	20.7	2,875	12.5	21.8
16	12	**Allied-Signal**	3,033	8.5	25.5	Diversified	377	23.2	53.6	12.4	1,839	18.4	20.5
17	19	**Arco Chemical**	2,700	38.3	100.0	Basic chemicals	722	81.4	100.0	26.7	2,548	100.0	28.3
18	17	**Rohm & Haas**	2,535	15.1	100.0	Basic chemicals	377	16.7	100.0	14.9	1,857	100.0	20.3
19	21	**Phillips Petroleum**	2,518	30.6	22.3	Petroleum	911	89.0	46.3	36.2	1,349	11.3	67.5
20	22	**Air Products**[e]	2,237	16.6	92.0	Basic chemicals	409	9.8	108.7	18.3	2,462	87.1	16.6
21	23	**Quantum Chemical**	2,219	18.3	76.0	Basic chemicals	711	104.7	93.6	32.1	1,465	50.4	48.6
22	18	**American Cyanamid**	2,167	10.5	47.2	Basic chemicals	214	11.0	38.9	9.9	1,519	49.4	14.1
23	20	**Bayer USA**	2,140	9.7	45.4	Diversified chemicals	118[f]	40.5	94.9	5.5	na	na	na
24	28	**Ashland Oil**[e]	2,090	27.2	25.5	Petroleum	102	13.3	24.7	4.9	754	17.7	13.5
25	25	**B. F. Goodrich**	2,074	19.1	85.8	Basic chemicals	308	46.5	88.5	14.8	1,358	79.9	22.7
26	32	**Atlantic Richfield**	1,903	38.0	10.4	Petroleum	na	na	na	na	na	na	na
27	26	**Hercules**	1,750	3.8	62.5	Basic chemicals	141	5.2	91.0	8.1	1,376	62.2	10.2
28	29	**Texaco**	1,711	7.8	5.1	Petroleum	379	193.8	11.8	22.2	1,029	3.9	36.8
28	—	**Himont**	1,711	46.8	100.0	Basic chemicals	526	69.1	100.0	30.7	1,044	100.0	50.3
30	31	**Ethyl**	1,674	19.1	61.6	Basic chemicals	309	20.1	70.4	18.5	1,141	22.7	27.1
31	43	**BP America**	1,507	59.8	9.8	Petroleum	na	na	na	na	na	na	na
32	33	**Dow Corning**	1,477	13.3	100.0	Specialty chemicals	151[f]	11.5	100.0	10.2	na	na	na
33	30	**FMC**	1,435	−3.6	43.7	Machinery	224	−7.7	58.4	15.6	1,234	54.1	18.1
34	37	**National Starch**	1,415	17.1	100.0	Specialty chemicals	200	14.1	100.0	14.1	1,110	100.0	18.0
35	34	**Rhône-Poulenc**	1,400	7.7	100.0	Specialty chemicals	na	na	na	na	na	na	na
36	35	**Olin**	1,366	10.9	59.2	Basic chemicals	105	6.1	58.3	7.7	953	49.1	11.0
37	40	**Akzo**	1,347	35.8	100.0	Basic chemicals	76	78.8	100.0	5.6	na	na	na
38	41	**Aluminum Co. of America**	1,215[d]	23.7	12.4	Nonferrous metals	419	569.2	24.1	34.5	2,577	24.5	16.3
39	38	**Unocal**	1,204	12.4	11.9	Petroleum	182	574.1	39.9	15.1	622	6.5	29.3
40	39	**Huntsman Chemical**	1,200	17.4	100.0	Basic chemicals	na	na	na	na	na	na	na
41	46	**Freeport-McMoRan**	1,130	31.5	58.1	Agrochemicals	198	85.9	39.3	17.5	894	24.0	22.1
42	42	**PPG Industries**	1,113	16.8	19.8	Glass products	255	82.1	27.6	22.9	1,048	20.3	24.3
43	28	**Ciba-Geigy**	1,098[g]	15.7	32.5	Specialty chemicals	na	na	na	na	na	na	na
44	—	**IMC Fertilizer**[h]	1,086	23.9	100.0	Agrochemicals	219	364.1	100.0	20.1	1,472	100.0	14.8
45	45	**Aristech**	1,065	15.9	100.0	Basic chemicals	196	63.2	100.0	18.4	676	100.0	29.0
46	58	**Georgia Gulf**	1,061	49.9	100.0	Basic chemicals	312	92.0	100.0	29.4	457	100.0	68.3
47	44	**Lubrizol**	1,036	10.2	92.0	Specialty chemicals	306	119.5	91.6	29.6	730	75.3	41.9
48	48	**Pennwalt**	1,024	21.0	100.0	Basic chemicals	135	31.5	100.0	13.2	738	100.0	18.3
49	47	**NL Industries**	1,007	17.2	100.0	Basic chemicals	261	24.8	100.0	25.9	841	100.0	31.0
50	59	**Solvay America**	1,000[d]	17.6	100.0	Basic chemicals	na	na	na	na	na	na	na

Rank 1988	Rank 1987		Chemical sales 1988 ($ millions)	Change from 1987	Chemical sales as % of total sales	Industry classification	Chemical operating profits[a] ($ millions)	Change from 1987	Chemical operating profits as % of total	Operating profit margin[b]	Identifiable chemical assets ($ millions)	Chemical assets as % of total assets	Operating return on chemical assets[c]
51	49	**Nalco Chemical**	$994	18.1%	100.0%	Specialty chemicals	$159	21.2%	100.0%	16.0%	$ 839	100.0%	18.9%
52	51	**CF Industries**	958	18.3	100.0	Agrochemicals	110	2461.4	100.0	11.5	991	100.0	11.1
53	36	**International Minerals**[h]	932	−23.2	100.0	Specialty chemicals	117	12.9	100.0	12.5	1,050	100.0	11.1
54	52	**Cabot**[e]	904	13.0	53.9	Basic chemicals	163	33.4	121.4	18.0	665	43.1	24.5
55	55	**Morton Thiokol**[h]	874	17.4	37.7	Diversified	149	14.7	52.2	17.0	795	41.4	18.7
56	60	**Terra Chemicals**	849	25.0	100.0	Agrochemicals	na	na	na	na	na	na	na
57	54	**International Flavors**	840	12.6	100.0	Specialty chemicals	209	14.0	100.0	24.9	882	100.0	23.7
58	53	**Eli Lilly**	798	6.6	19.6	Drugs	126	48.9	11.3	15.8	787	15.0	16.1
59	64	**Vista Chemicals**[e]	781	28.3	100.0	Basic chemicals	195	63.3	100.0	24.9	521	100.0	37.4
60	68	**Farmland Industries**	767	46.2	27.3	Agricultural supplies	75	5838.7	66.7	9.8	324	44.5	23.1
61	63	**Witco**	758[g]	21.5	47.8	Specialty chemicals	62	2.2	43.0	8.2	361	32.4	17.2
62	67	**Uniroyal Chemical**	734	24.3	100.0	Specialty chemicals	86	17.2	100.0	11.7	1,016	100.0	8.5
63	57	**Engelhard**	727	2.0	30.9	Diversified	107	22.7	85.5	14.8	880	62.3	12.2
64	—	**Sterling Chemical**	699	69.2	100.0	Basic chemicals	312	246.4	100.0	44.7	294	100.0	106.1
65	66	**H. B. Fuller**[i]	685	14.7	100.0	Specialty chemicals	46	−2.8	100.0	6.8	421	100.0	11.0
66	61	**American Petrofina**	682	1.7	27.7	Petroleum	281	38.2	113.7	41.1	360	15.5	77.9
67	65	**Henkel**	650	8.3	100.0	Specialty chemicals	na	na	na	na	na	na	na
68	72	**Great Lakes Chemical**	558	16.6	100.0	Specialty chemicals	143	68.7	100.0	25.7	664	100.0	21.6
69	—	**Borden Chemicals**	553	na	100.0	Basic chemicals	121	−41.8	100.0	21.9	605	100.0	20.0
70	76	**GAF**	545	26.3	56.7	Specialty chemicals	150	15.4	83.2	27.5	na	na	na
71	73	**Kerr-McGee**	518	11.6	19.3	Petroleum	102	43.7	43.8	19.7	671	22.3	15.2
72	69	**Pfizer**	512	−0.2	9.5	Drugs	49	−29.7	4.4	9.5	489	6.4	10.0
73	75	**Tyler**	485	11.3	75.3	Diversified	37	1.3	85.0	7.6	202	65.7	18.3
74	76	**Merck**	466	8.1	7.8	Drugs	62	6.6	3.3	13.2	426	7.0	14.4
75	79	**Sun Co.**	461	24.4	4.7	Petroleum	na	na	na	na	na	na	na
76	—	**Hoffmann-La Roche**	450	4.2	23.7	Drugs	na	na	na	na	na	na	na
77	78	**Betz Laboratories**	448	16.0	100.0	Specialty chemicals	na	na	na	na	na	na	na
78	80	**Ferro**	443	22.3	43.9	Specialty materials	18	−34.8	17.7	4.1	242	45.8	7.5
79	88	**Dexter**	424	9.7	51.3	Rubber products	26	−28.1	28.3	6.1	298	47.6	8.7
80	83	**Loctite**	417	23.4	100.0	Specialty chemicals	66	45.1	100.0	15.8	347	100.0	19.0
81	82	**Union Camp**	398	14.3	15.0	Diversified	30	42.8	6.0	7.5	294	9.5	10.2
82	85	**Lonza**	395	26.6	100.0	Specialty chemicals	na	na	na	na	na	na	na
83	86	**Vulcan Materials**	383	28.5	36.3	Nonmetallic minerals	66	102.3	31.9	17.3	na	na	na
84	87	**Stepan**	333	15.3	100.0	Specialty chemicals	21	6.9	100.0	6.2	186	100.0	11.1
85	90	**Sigma-Aldrich**	302	22.1	80.5	Specialty chemicals	77	20.7	86.9	25.5	314	87.4	24.5
86	89	**Petrolite**[j]	274	10.4	91.0	Specialty chemicals	21	−1.2	127.5	7.7	186	76.7	11.4
87	84	**Chemed**	270	−19.6	54.0	Specialty chemicals	33	−19.0	66.6	12.4	133	48.3	25.1
88	94	**Georgia-Pacific**	241	27.5	2.5	Wood products	na	na	na	na	na	na	na
89	95	**First Mississippi**	237	31.2	74.6	Agrochemicals	23	190.0	101.4	9.8	104	34.6	22.3
90	92	**Crompton & Knowles**	232	21.8	80.2	Specialty chemicals	26	33.5	71.3	11.4	159	77.1	16.7
91	—	**Calgon Carbon**	226	32.5	100.0	Basic chemicals	51	30.6	100.0	22.6	196	100.0	26.1
92	—	**Sherex**	200	na	100.0	Specialty chemicals	na	na	na	na	na	na	na
93	96	**Mississippi Chemical**	186	6.6	100.0	Farm cooperative	18	def	100.0	9.8	322	100.0	5.7
94	97	**Quaker Chemical**	167	12.9	100.0	Specialty chemicals	17	3.5	100.0	10.4	121	100.0	14.3
95	99	**LeaRonal**[k]	157	23.0	100.0	Specialty chemicals	14	12.4	100.0	9.0	88	100.0	15.9
96	—	**Lawter International**	126	12.3	100.0	Specialty chemicals	27	11.5	100.0	21.8	125	100.0	21.9
97	100	**UGI**	124	6.7	28.5	Natural gas	4	200.8	6.9	3.6	168	27.2	2.6
98	98	**Agway**	123	−7.6	3.4	Farm cooperative	na	na	na	na	na	na	na
99	—	**Cambrex**	120	11.5	100.0	Specialty chemicals	13	−4.3	100.0	10.5	na	na	na
100	—	**Products Research**	100	5.4	100.0	Specialty chemicals	17	−11.7	100.0	16.6	68	100.0	24.6

a Operating profit is sales less administrative expenses and costs of sales. **b** Operating profit from chemicals as a percentage of sales. **c** Chemical operating profit as a percentage of identifiable chemical assets. **d** Chemical sales include significant amounts of nonchemical products. **e** Fiscal year ends Sept. 30. **f** Chemical net income. **g** Does not include all chemical sales. **h** Fiscal year ends June 30. **i** Fiscal year ends Nov. 30. **j** Fiscal year ends Oct. 31. **k** For fiscal year ended Feb. 29, 1988. **na** = not available.

FINANCIAL ANALYSIS: Chemical firms generally improved their performance in 1988

									CAPITAL SPENDING[f]				
		Profit margin[a]	Return on investment[b]	Debt as % debt plus equity	% total sales abroad[c]	% total assets abroad[d]	Sales per employee[e]	Dividends as % of net income	as % of sales	as % of net plant	R&D as % of sales	Sales as % of assets	Net plant as % of gross plant
SALES OVER $1 BILLION													
Air Products[g]	1988	8.8%	4.5%	34.4%	24.0%	29.9%	$183	28.2%	16.8%	19.9%	3.0%	81.1%	50.5%
	1987	7.5	2.5	35.0	22.0	26.7	176	31.6	15.1	16.8	2.7	78.9	33.6
American Cyanamid	1988	6.7	5.6	18.9	38.3	24.3	129	34.1	8.1	24.0	8.0	100.0	49.8
	1987	6.3	5.2	23.1	37.1	25.6	122	35.4	6.4	19.3	7.5	100.9	48.1
Cabot[g]	1988	3.6	2.8	34.5	36.8	9.6	322	40.5	10.1	20.3	1.7	108.6	52.1
	1987	2.8	1.9	27.2	39.2	20.6	279	65.1	5.7	10.2	2.4	97.3	52.9
Dow Chemical	1988	14.4	11.1	31.5	55.1	53.5	301	19.1	10.0	25.4	4.6	102.7	42.8
	1987	9.3	6.5	39.6	55.6	49.0	252	33.0	7.4	17.9	5.0	93.2	41.1
Ethyl	1988	11.5	11.0	35.0	21.5	3.6	193	22.5	7.5	21.0	2.9	38.3	49.3
	1987	11.2	11.8	38.8	22.0	9.0	172	25.5	8.0	20.5	2.9	86.8	50.4
Georgia Gulf	1988	18.3	38.3	14.2	na	na	776	8.6	2.4	14.8	na	231.9	69.0
	1987	13.0	25.0	22.6	na	na	712	6.0	1.4	8.3	na	229.2	65.2
B. F. Goodrich	1988	8.7	8.1	21.1	28.4	18.5	196	24.8	7.5	19.3	2.4	116.6	58.3
	1987	3.9	3.8	25.6	25.2	18.2	181	55.8	6.6	16.0	2.4	111.8	58.5
W. R. Grace	1988	4.0	3.8	49.3	37.0	28.6	127	52.1	7.2	20.6	2.1	109.0	49.8
	1987	3.1	2.7	45.5	37.9	27.8	115	84.0	5.4	14.3	2.4	100.9	47.4
Hercules	1988	4.3	3.1	17.3	22.6	13.3	123	77.1	9.0	21.6	2.7	84.3	49.6
	1987	9.9	6.8	18.2	21.3	12.0	116	36.8	7.6	19.1	2.7	77.1	49.9
International Minerals[h]	1988	7.1	7.1	25.9	17.3	14.5	213	41.0	5.5	18.2	4.4	82.0	71.1
	1987	0.9	0.5	40.7	13.7	13.7	127	276.7	3.8	4.9	3.6	67.3	55.7
Lubrizol	1988	11.7	10.1	7.7	53.6	35.1	234	48.0	4.9	18.3	5.8	115.1	40.8
	1987	8.0	6.7	8.3	55.2	35.9	210	59.3	4.1	14.1	6.1	107.9	42.2
Monsanto	1988	7.1	5.9	27.0	37.1	27.4	182	35.7	7.1	18.8	7.8	98.0	45.4
	1987	5.7	4.5	28.6	36.1	25.1	154	48.6	6.6	16.4	8.1	90.3	45.7
Olin	1988	4.2	3.3	33.8	10.1	9.2	141	36.7	6.4	18.4	2.5	119.0	37.0
	1987	4.0	2.9	35.9	7.3	7.7	137	47.4	6.0	15.8	3.2	114.5	36.2
PPG Industries	1988	8.3	6.8	27.2	30.0	28.8	155	30.0	7.3	14.9	4.0	109.0	55.1
	1987	7.3	5.7	29.7	29.2	28.9	141	34.9	8.2	15.9	4.4	103.9	56.5
Pennwalt	1988	4.7	3.7	40.2	34.8	27.7	205	63.3	4.6	13.0	3.0	107.8	44.5
	1987	4.7	3.8	31.5	28.4	29.7	127	58.6	4.8	12.7	3.9	109.7	47.7
Quantum Chemical	1988	12.3	11.0	144.0	na	na	na	17.4	11.4	25.5	na	100.5	67.4
	1987	5.6	5.0	41.0	na	na	na	50.6	6.0	11.2	na	99.4	67.8
Rohm & Haas	1988	9.1	7.4	19.3	42.8	30.2	204	29.1	13.3	36.1	6.2	113.1	45.3
	1987	8.9	7.2	19.7	41.5	30.0	183	30.3	10.1	30.4	6.4	112.7	41.6
Union Carbide	1988	8.0	5.6	55.6	30.8	36.9	189	23.4	8.1	15.2	1.9	98.6	49.0
	1987	3.4	2.1	69.7	30.9	36.4	160	84.1	7.3	11.6	2.3	87.6	50.3
Witco	1988	4.5	4.9	29.4	19.5	104.9	209	43.5	4.5	18.0	1.5	142.3	48.7
	1987	4.4	4.6	32.1	18.9	15.3	184	40.9	4.8	18.4	1.6	135.2	49.4
MEDIAN 1988		8.0%	5.9%	29.4%	30.8%	27.7%	$195	34.1%	7.5%	19.3%	3.0%	108.6%	49.6%
MEDIAN 1987		5.7%	4.6%	31.5%	29.2%	25.6%	$166	47.4%	6.4%	15.9%	3.2%	100.9%	49.4%

2 Finances of the U.S. Chemical Industry

		Profit margin[a]	Return on investment[b]	Debt as % debt plus equity	% total sales abroad[c]	% total assets abroad[d]	Sales per employee[e]	Dividends as % of net income	CAPITAL SPENDING[f]		R&D as % of sales	Sales as % of assets	Net plant as % of gross plant
									as % of sales	as % of net plant			
SALES LESS THAN $1 BILLION													
Betz Laboratories	1988	10.8%	12.2%	0.0%	18.0%	20.0%	$142	50.8%	9.7%	28.4%	3.6%	140.5%	55.7%
	1987	10.5	11.3	0.0	16.8	19.7	136	57.4	6.6	19.0	3.7	134.5	52.4
Calgon Carbon	1988	13.0	13.6	18.3	34.4	35.1	na	7.1	7.1	18.7	2.0	115.2	77.7
	1987	10.3	10.6	20.0	25.4	29.6	na	8.3	2.6	5.9	1.7	111.4	81.2
Chemed	1988	4.7	8.3	44.8	12.7	11.1	80	77.3	3.3	24.0	0.7	137.4	58.0
	1987	6.0	10.4	29.1	13.1	11.3	71	70.1	2.6	18.4	0.9	129.0	55.9
Crompton & Knowles	1988	5.8	8.4	35.2	18.4	21.2	181	30.1	2.4	16.1	2.1	140.9	55.4
	1987	5.0	7.5	14.5	17.3	23.8	182	33.9	1.5	12.4	2.0	175.7	46.8
First Mississippi[h]	1988	10.2	5.7	1.8	25.1	na	na	14.8	19.0	36.2	na	96.3	35.2
	1987	6.7	3.5	26.7	24.0	na	na	25.8	7.0	12.8	na	94.1	34.3
H. B. Fuller[i]	1988	3.1	4.5	35.5	46.3	50.1	132	23.7	5.9	24.9	2.1	157.7	63.4
	1987	4.3	6.7	17.0	45.4	55.8	130	14.7	4.9	23.0	2.1	181.2	61.8
Great Lakes Chemical	1988	18.5	16.3	3.8	17.9	12.8	na	11.8	8.4	20.1	3.4	84.0	57.3
	1987	11.6	9.6	9.7	19.2	14.7	na	1.2	7.4	16.1	3.4	82.9	59.5
International Flavors	1988	15.3	12.1	0.0	70.1	48.0	201	47.1	4.8	17.6	5.9	95.2	55.1
	1987	14.3	10.3	0.0	70.3	50.4	181	46.9	4.9	16.8	6.0	85.3	55.7
Lawter International	1988	16.6	14.9	5.7	44.3	33.2	na	59.5	3.6	18.4	2.5	100.5	45.2
	1987	14.9	13.1	20.6	44.9	36.3	na	58.7	1.3	6.6	2.3	101.9	45.7
Loctite[h]	1988	10.0	11.4	16.1	58.4	62.2	127	23.7	3.5	19.8	3.5	120.2	57.1
	1987	9.1	9.6	5.5	54.3	57.4	107	27.0	4.6	21.9	3.6	111.3	59.1
Nalco Chemical	1988	10.7	10.8	17.4	27.8	20.4	185	47.6	6.2	19.8	3.7	118.5	48.0
	1987	9.5	9.0	13.0	26.1	21.8	166	58.8	6.8	18.8	4.2	112.7	50.1
Petrolite[j]	1988	4.3	3.7	2.2	30.2	34.3	na	97.5	6.8	19.6	4.1	124.7	44.7
	1987	4.3	3.3	1.4	31.8	32.8	na	107.6	6.8	19.4	4.3	112.2	45.0
Quaker Chemical	1988	7.0	8.9	5.7	40.6	30.7	170	29.6	3.2	16.1	5.5	137.6	52.9
	1987	7.0	8.2	6.0	40.7	31.3	153	32.7	2.5	11.3	5.7	124.7	54.5
Sigma-Aldrich	1988	15.0	13.9	6.0	18.0	15.4	117	14.4	9.5	29.8	na	104.3	68.6
	1987	13.7	12.8	7.3	16.8	16.1	105	16.9	6.8	21.2	na	106.9	68.7
Stepan	1988	4.0	4.6	40.5	na	na	324	19.8	6.1	19.5	3.9	179.4	47.9
	1987	3.8	4.1	42.6	na	na	288	21.8	8.9	26.0	3.9	167.3	49.5
Sterling Chemical[g]	1988	30.6	67.7	48.8	na	na	na	89.0	2.4	9.8	na	237.6	86.7
	1987	12.4	17.6	68.9	na	na	na	2.0	3.2	7.8	na	145.8	92.6
Vista Chemical[g]	1988	15.9	21.1	60.2	9.8	na	na	4.3	6.2	17.4	na	150.0	72.0
	1987	8.0	8.9	53.9	6.4	na	381	2.5	3.4	7.8	na	121.8	77.0
MEDIAN 1988		10.8%	10.8%	17.4%	25.1%	21.2%	$156	29.6%	6.1%	19.6%	3.5%	124.7%	55.7%
MEDIAN 1987		9.1%	9.6%	14.5%	25.4%	29.6%	$153	27.0%	4.9%	16.8%	3.6%	112.7%	55.7%

Note: Net income is from continuing operations, excluding extraordinary and nonrecurring items where possible. **a** Net income as a percentage of sales. **b** Net income as a percentage of current assets plus gross plant. **c** Consolidated sales only. **d** Foreign identifiable assets as a percentage of total assets. **e** Thousands of dollars. **f** Actual spending on construction of new facilities and purchase of new equipment and land in consolidated businesses. **g** Fiscal year ended Sept. 30. **h** Fiscal year ended June 30. **i** Fiscal year ended Nov. 30. **j** Fiscal year ended Oct. 31. **na** = not available.

Capital spending by U.S. chemical producers grew at an astonishing rate in 1988 compared with 1987, scoring the best year-to-year increase in the past 10 years, according to both the C&EN survey of 26 major chemical producers and the Department of Commerce's survey of chemical industry capital spending.

The increase in outlays for new plant and equipment for the 26 chemical makers surveyed by C&EN was 34%, while the much wider survey conducted by the Department of Commerce showed a 17% increase. If capital spending levels increase in 1989 as the Department of Commerce's survey indicates, chemical producers will boost spending another 11% this year.

Even as many debottlenecking projects for major commodity chemicals—such as propylene, ethylene, vinyl chloride, and acrylonitrile—have either come on stream or are about to do so, demand continues relatively strong. As a result, many producers seem to have abandoned their earlier cautious approach. Instead of just slating debottlenecking projects, they have announced new plant projects. However, whether the announcements presage another building boom reminiscent of the industry's binge in the 1970s or merely are being announced to discourage building by competitors remains to be seen. Best bet is that there is some truth in both views.

Among the 26 chemical producers in C&EN's survey who have increased their capital expenditures significantly above the 34% average are Quantum Chemical, Cabot, Crompton & Knowles, Dow Chemical, Chemed, and Rohm & Haas.

Perhaps because of the recent strength of the dollar, many chemical producers are planning increases in capital expenditures overseas. A Commerce Department survey in-

INDUSTRY CAPITAL SPENDING: 1989 will bring second big increase in a row for chemicals

$ Billions	1989[a]	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979
Chemicals	$ 21.31	$ 19.25	$ 16.42	$ 16.81	$ 16.44	$ 15.32	$ 12.96	$ 12.66	$ 13.11	$ 11.63	$ 9.81
Iron and steel	6.61	6.16	4.69	3.32	4.12	3.54	3.25	3.78	3.48	3.44	3.21
Nonferrous metals	3.04	2.77	2.16	1.93	1.88	2.13	1.74	1.90	2.51	2.13	1.65
Paper	15.21	11.23	9.01	8.77	8.59	7.21	5.92	5.60	6.11	6.52	5.24
Petroleum	19.32	19.93	17.12	17.92	26.71	25.53	23.14	26.39	25.98	19.57	15.24
Rubber	4.15	3.86	3.52	3.89	3.86	3.11	2.46	2.16	2.15	2.03	2.46
Stone, clay, glass	3.66	3.59	3.37	3.14	3.40	3.09	2.77	2.90	3.41	3.98	3.99
All manufacturing	178.66	165.70	145.90	142.69	153.48	138.82	116.20	120.68	126.54	112.33	95.92

a Estimate **Source:** Department of Commerce

Chemical industry's backlog of unspent funds showed 50% increase last year

$ Billions	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978
Chemicals	$ 10.6	$ 7.0	$ 6.2	$ 8.0	$ 7.8	$ 7.5	$ 7.4	$ 9.4	$ 9.8	$ 8.5	$ 7.2
Iron and steel	2.7	1.4	0.5	1.1	2.1	2.2	2.7	5.4	3.9	4.5	4.0
Nonferrous metals	1.6	1.7	1.6	2.3	2.5	3.2	3.2	3.7	3.7	2.9	2.7
Paper	12.3	6.3	4.4	4.3	5.9	4.0	5.1	5.1	4.0	4.2	3.2
Petroleum	14.6	15.2	16.7	26.2	24.7	22.3	22.9	29.7	26.7	16.1	14.6
Rubber	2.8	1.7	1.9	3.1	1.6	1.1	1.0	0.9	1.0	0.9	0.9
Stone, clay, glass	2.8	2.4	1.8	2.0	2.2	1.5	1.6	1.9	2.0	2.3	2.4
All manufacturing	101.7	76.8	69.7	95.0	94.4	73.7	70.8	92.7	91.9	76.7	63.4

Note: Figures are for fourth quarter of each year **Source:** Conference Board

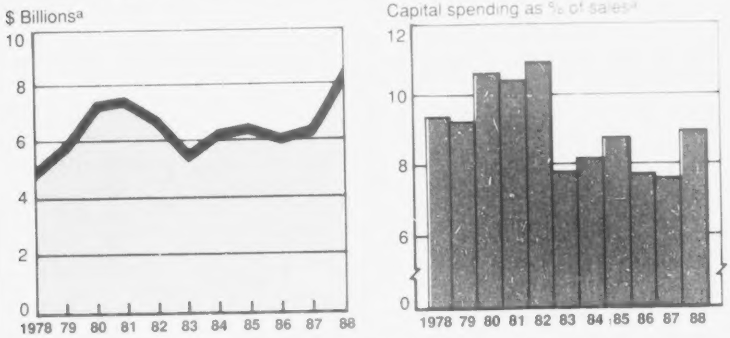
Capital spending by chemical firms abroad is still on the upswing

$ Billions[a]	1989[b]	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979
Chemicals and allied products	$ 5.2	$ 4.4	$ 3.7	$ 3.1	$ 2.7	$ 2.4	$ 2.3	$ 2.8	$ 3.0	$ 3.0	$ 2.6
Metals, primary and fabricated	1.2	0.9	0.8	0.9	0.9	1.0	0.9	0.9	0.8	0.9	0.6
Petroleum	13.7	13.3	9.8	9.6	13.7	14.1	15.9	19.7	15.8	14.8	11.0
All manufacturing	24.5	20.8	17.2	16.4	14.9	13.6	13.6	16.8	19.2	19.5	15.4

a By majority-owned affiliates of U.S. companies b Planned **Source:** Department of Commerce dicates a spending increase abroad this year by U.S. chemical companies of 18%. These investments will not only serve the companies' ambitions for increasing their share in a global market but also would boost U.S. companies' foreign currency earnings if their exports were to suffer should a stronger dellar ultimately make U.S. products more expensive for overseas buyers.

Despite the rise in expenditures directed toward capital projects, spending as a percentage of sales still lags historic highs. The spending increase in 1988 to 8.9% of sales is still below the 10.9% level of 1982.

Last year's strength in chemical capital spending lifted it to the highest level relative to sales since 1982



a Worldwide data for 26 major chemical producers. **Source:** Company data

CHEMICAL CAPITAL SPENDING: 1988 witnessed a sharp upsurge

$ Millions	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978
Air Products	$ 409	$ 323	$ 367	$ 392	$ 263	$ 246	$ 347	$ 323	$ 364	$ 246	$ 200
American Cyanamid	374	268	263	203	200	165	171	181	196	235	251
Cabot[a]	170	83	80	184	505	80	152	194	137	98	128
Chemed	15	9	9	7	9	5	4	4	4	6	3
Crompton & Knowles	7	4	4	3	3	2	3	7	10	8	5
Dow Chemical	1670	995	890	806	781	630	829	1176	1184	1268	1075
Du Pont[b]	2029	1674	1587	1515	1319	1276	1300	1420	1297	864	714
Ethyl	151	139	134	90	103	85	92	141	156	123	96
B. F. Goodrich	181	143	144	202	153	115	144	205	184	192	115
W. R. Grace	418	243	199	348	380	353	560	657	658	514	313
Great Lakes Chemical	47	35	18	21	29	20	29	47	21	18	9
Hercules	251	205	257	234	218	168	174	167	229	186	116
Loctite	14	15	9	11	6	10	11	13	14	9	6
Lubrizol	55	42	41	40	30	25	52	75	92	51	44
Monsanto	590	505	520	645	614	560	673	668	781	566	480
Nalco Chemical	62	57	64	60	53	41	56	59	35	39	34
Olin	147	115	128	154	165	123	129	186	172	161	163
PPG Industries	410	426	356	452	315	450	452	376	401	252	261
Pennwalt	47	55	54	90	87	70	76	53	53	66	61
Petrolite	20	19	25	24	11	9	24	15	17	12	7
Quaker Chemical	5	4	5	6	4	2	2	1	5	3	4
Quantum Chemical	334	154	102	76	116	71	66	44	49	58	106
Rohm & Haas	338	222	179	159	124	72	126	182	93	68	66
Stepan	20	26	14	19	12	10	16	12	9	14	14
Union Carbide	671	502	524	649	670	761	1179	1186	1129	831	688
Witco	72	69	60	76	85	55	54	83	73	49	51
TOTAL	**$8507**	**$6332**	**$6033**	**$6466**	**$6255**	**$5404**	**$6721**	**$7475**	**$7363**	**$5937**	**$5010**
ANNUAL CHANGE	**34%**	**5%**	**−7%**	**3%**	**16%**	**−20%**	**−10%**	**2%**	**24%**	**19%**	**−1%**

Note: Figures are for worldwide spending on construction, equipment, and land in consolidated businesses. Where possible, acquisition costs and investments in nonconsolidated businesses are excluded. **a** Includes acquisitions and investments. **b** Excludes Conoco. **Source:** Company data

2 Finances of the U.S. Chemical Industry

SHIPMENTS: Chemicals outpaced all manufacturing by wide margin last year

$ Billions	1988[a]	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	Annual change 1987-88	Annual change 1978-88
All manufacturing industries	$2611.6	$2390.0	$2260.3	$2279.1	$2254.4	$2054.9	$1960.2	$2017.5	$1852.7	$1727.2	$1523.4	9%	6%
Chemicals and allied products	240.5	212.7	197.1	197.3	198.2	183.2	170.7	180.5	162.5	147.7	129.8	13	6
Industrial chemicals[b]	67.8	59.5	54.1	59.6	61.5	56.6	53.2	62.7	57.3	52.3	44.8	14	4
Drugs, soap, and toiletries	73.1	67.1	65.8	60.9	57.5	54.4	50.7	46.9	41.9	36.7	34.7	9	8
Petroleum and coal products	124.2	124.5	124.9	179.1	189.0	192.6	208.9	224.1	198.7	148.4	103.9	0	2
Rubber and plastic products, nec	91.1	80.5	73.4	71.3	69.5	60.3	55.4	53.2	47.3	46.8	43.2	13	8
Paper and allied products	124.2	110.3	97.9	93.4	94.8	84.6	79.9	80.2	72.8	65.2	57.0	13	8

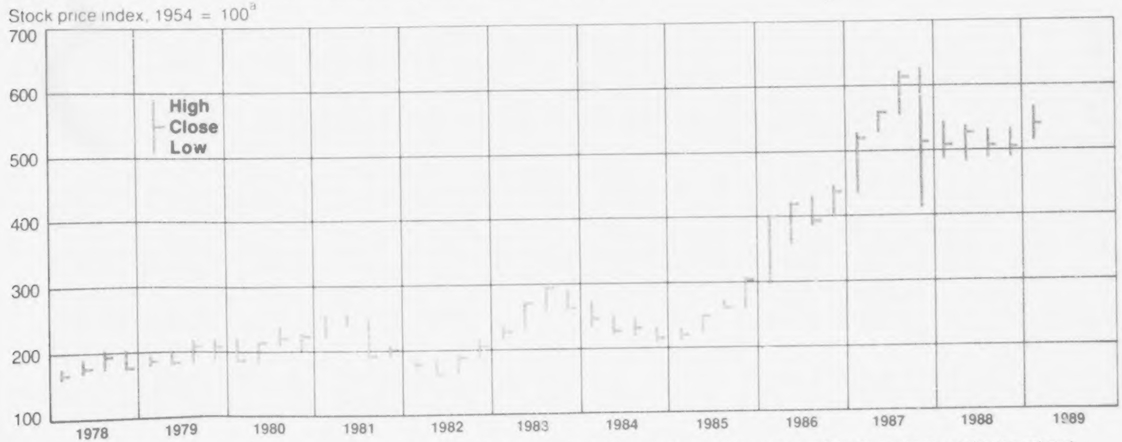
a Preliminary. b Excluding pigments. **nec** = not elsewhere classified. **Source:** Department of Commerce

PRICES: All chemical products rose, some steeply

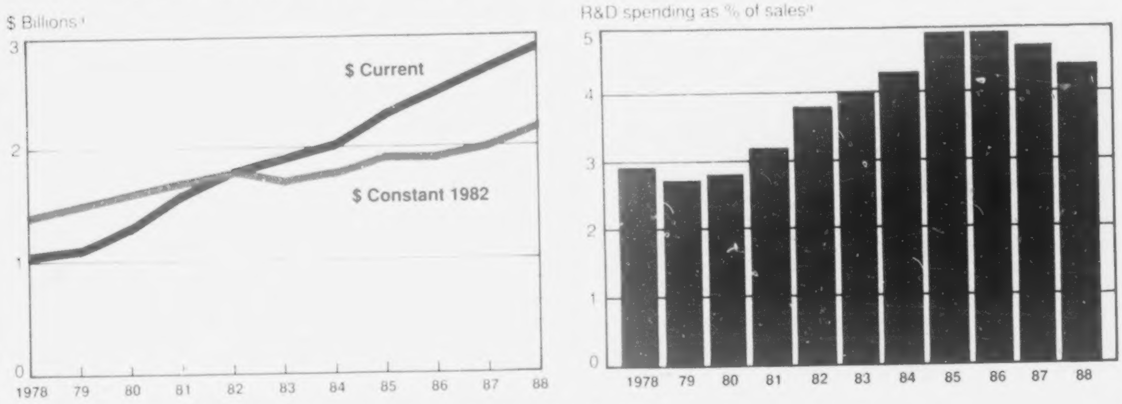
Producer price indexes,[a] 1982 = 100	Annual average 1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	Annual change 1987-88	Annual change 1978-88
All commodities	106.9	102.8	100.2	103.1	103.7	101.3	100.0	98.0	89.8	78.7	69.9	4%	4%
Industrial commodities	106.3	102.6	99.9	103.7	103.3	101.1	100.0	97.4	88.0	75.7	67.0	4	5
Chemicals and allied products	116.3	106.4	102.5	103.7	102.9	100.2	100.0	98.4	89.1	76.1	68.0	9	6
Industrial chemicals	106.8	95.5	91.5	96.0	96.8	97.3	100.0	103.0	91.9	74.9	64.0	12	5
Prepared paint	112.2	108.1	107.0	105.3	103.7	100.7	100.0	95.0	89.5	77.8	73.1	4	4
Paint materials	115.7	107.3	104.4	109.5	108.2	100.3	100.0	98.5	89.9	79.2	69.8	8	5
Drugs and pharmaceuticals	148.4	139.1	129.9	122.2	114.2	107.7	100.0	92.1	83.1	75.9	70.5	7	8
Fats and oils, inedible	110.9	92.7	80.5	110.6	139.1	106.2	100.0	110.7	111.6	141.1	118.3	20	−1
Agricultural chemicals and chemical products	104.5	96.4	94.2	96.2	97.4	96.0	100.0	97.5	87.9	73.3	67.8	8	4
Plastic resins and materials	132.4	110.3	104.4	107.5	108.9	102.4	100.0	102.0	98.5	83.2	70.5	20	7
Other chemicals and allied products	111.9	107.0	105.8	105.2	102.7	101.3	100.0	94.1	83.1	71.0	67.3	5	5
Rubber and plastics products	109.3	103.0	101.9	101.9	102.2	100.8	100.0	96.4	90.1	80.5	72.4	6	4

a Formerly called "wholesale price indexes." **Source:** Department of Labor

Prices of chemical stocks move up toward 1987 peak



a C&EN weighted stock price index of American Cyanamid, Dow Chemical, W. R. Grace, Hercules, Monsanto, Rohm & Haas, and Union Carbide; weighted according to number of shares outstanding for each company.



Despite higher outlays, R&D spending by chemical firms has declined relative to sales

a R&D spending by [illegible] chemical producers. **Sources:** Company data, Battelle Columbus Laboratories

R&D SPENDING: Major chemical producers' budgets have more than doubled since 1980

$ Millions	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978
CHEMICAL COMPANIES											
Air Products	$ 72	$ 57	$ 61	$ 51	$ 44	$ 40	$ 37	$ 32	$ 30	$ 24	$ 23
American Cyanamid	365	314	278	251	232	208	185	166	148	130	108
Dow Chemical	772	670	605	547	507	492	460	404	314	269	232
Ethyl	59	50	47	47	40	39	39	37	34	29	25
W. R. Grace	119	107	94	92	81	73	64	57	45	42	37
Hercules	74	74	71	76	72	74	74	65	57	50	43
International Flavors	50	45	39	34	32	32	31	30	29	27	24
Lubrizol	65	62	51	44	33	37	36	33	28	23	21
Monsanto	648	615	596	470	370	290	264	233	208	161	136
Nalco	37	35	33	32	32	30	33	30	28	21	17
Olin	58	62	56	53	52	49	45	38	31	26	25
Pennwalt	31	45	45	39	36	33	31	27	24	22	23
Petrolite	12	12	12	12	12	13	10	8	7	6	5
PPG Industries	227	227	204	176	150	127	127	119	103	83	70
Rohm & Haas	156	142	133	124	109	100	92	77	67	54	49
Union Carbide	159	159	148	275	265	245	240	207	166	161	156
TOTAL	**$2904**	**$2676**	**$2473**	**$2323**	**$2067**	**$1882**	**$1768**	**$1563**	**$1319**	**$1128**	**$994**
ANNUAL CHANGE	**9%**	**8%**	**6%**	**12%**	**10%**	**6%**	**13%**	**18%**	**17%**	**13%**	**8%**
PHARMACEUTICAL & DIVERSIFIED COMPANIES											
Allied-Signal	$ 647	$ 667	$ 734	$ 470	$ 389	$ 383	$ 177	$ 152	$ 105	$ 70	$ 56
Du Pont	1319	1223	1156	1144	1097	966	879	718	591	509	461
Eastman Kodak	1147	992	1059	976	838	746	710	615	520	459	389
Eli Lilly	500	466	427	370	341	294	267	235	201	178	150
FMC	144	132	146	149	121	102	105	94	81	69	54
Merck & Co.	650	566	480	426	393	356	320	274	234	188	161
Morton Thiokol	45	40	38	34	28	21	7	6	6	5	4
Pfizer	473	401	336	287	255	230	199	179	162	139	117
Upjohn	380	356	314	284	247	218	185	162	139	122	109
TOTAL	**$5305**	**$4843**	**$4690**	**$4140**	**$3709**	**$3316**	**$2849**	**$2435**	**$2039**	**$1739**	**$1501**
ANNUAL CHANGE	**10%**	**3%**	**13%**	**12%**	**12%**	**16%**	**17%**	**19%**	**17%**	**16%**	**17%**

Note: Prior years not restated to reflect company revisions. **Source:** Company data

INDUSTRY BALANCE SHEET: Assets rise more than liabilities, swelling stockholders' stake

Industrial chemicals and synthetics

Assets	1988 ($ billions)	1987 ($ billions)	Change
Current assets			
Cash	$ 1.75	$ 1.72	2%
Short-term securities	2.01	1.95	3
Receivables	17.32	15.02	15
Inventories	14.54	12.98	12
Other current assets	4.38	3.88	13
Total	40.00	35.55	13
Fixed assets			
Depreciable fixed assets	88.74	85.84	3
Land and mineral rights	5.47	3.12	75
Less: accumulated depreciation and depletion	46.52	45.56	2
Net fixed assets	47.69	43.40	10
Other assets, including investments and intangibles	32.91	30.98	6
TOTAL ASSETS	$120.60	$109.93	10%

Source: Bureau of the Census

Liabilities and stockholders' equity	1988 ($ billions)	1987 ($ billions)	Change
Current liabilities			
Short-term debt	$ 4.39	$ 3.97	11%
Accounts payable	8.34	8.04	4
Accrued income taxes	1.66	1.92	−14
Current portion of long-term debt	1.78	1.52	17
Other current liabilities	12.07	10.85	11
Total	28.24	26.30	7
Long-term debt	28.31	28.29	0
Other liabilities, including deferred taxes and minority interest	12.93	10.00	29
TOTAL LIABILITIES	69.48	64.59	8
Stockholders' equity			
Capital stock and other capital	15.98	16.31	−2
Retained earnings	35.14	29.03	21
TOTAL STOCKHOLDERS' EQUITY	51.12	45.34	13
TOTAL LIABILITIES AND STOCKHOLDERS' EQUITY	$120.60	$109.93	10%

DEBT RATIOS: Down slightly last year for chemical firms as growth in debt slows

$ Billions	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978
INDUSTRIAL CHEMICALS AND SYNTHETICS											
Long-term debt	$28.3	$28.3	$20.8	$19.2	$18.1	$19.4	$22.0	$21.4	$16.8	$14.8	$13.6
Stockholders' equity	$51.1	$45.3	$41.6	$40.8	$46.5	$45.3	$45.9	$42.5	$39.8	$32.3	$29.3
Debt ratio[a]	35.6%	38.4%	33.4%	32.0%	28.0%	30.0%	32.4%	33.5%	29.6%	31.4%	31.8%
CHEMICALS AND ALLIED PRODUCTS											
Long-term debt	$57.6	$53.6	$46.8	$38.2	$33.8	$36.2	$38.2	$36.9	$28.3	$24.9	$32.5
Stockholders' equity	$117.8	$106.9	$100.8	$100.3	$100.3	$97.2	$95.3	$89.9	$79.5	$67.4	$60.8
Debt ratio[a]	32.8%	33.4%	31.7%	27.6%	25.2%	27.2%	28.6%	29.1%	26.3%	27.0%	27.9%
ALL MANUFACTURING											
Long-term debt	$531.5	$451.7	$407.5	$367.0	$324.2	$286.6	$293.1	$266.5	$236.2	$204.8	$182.0
Stockholders' equity	$976.5	$912.8	$878.1	$870.7	$883.6	$837.6	$783.0	$762.3	$699.7	$624.0	$560.8
Debt ratio[a]	35.2%	33.1%	31.7%	29.6%	26.8%	25.5%	27.2%	25.9%	25.2%	24.7%	24.5%

Note: Because of changes in accounting rules and industry classifications, numbers over the entire range of years are not strictly comparable. [a] Long-term debt as a percentage of long-term debt plus stockholders' equity. **Source:** Bureau of the Census

CASH FLOW: Profits are a bigger source, plant outlay a growing use of chemical company funds

$ Millions, % of total	1988		1987		1986		1985		1984	
SOURCES OF FUNDS										
Net income	$ 7,551	38.2%	$ 5,697	29.6%	$ 3,414	13.6%	$ 986	6.5%	$ 3,859	29.7%
Depreciation and depletion	5,561	28.1	5,284	27.5	5,117	20.4	5,010	32.8	4,710	36.2
Deferred taxes	311	1.6	311	1.6	568	2.3	−34	−0.2	507	3.9
Other internal sources	2,489	12.6	4,272	22.2	6,084	24.3	6,707	43.9	2,357	18.1
Long-term debt	3,624	18.3	2,949	15.3	8,773	35.0	2,356	15.4	1,441	11.1
Stock	236	1.2	732	3.8	1,091	4.4	264	1.7	136	1.0
TOTAL	**$19,772**	**100.0%**	**$19,245**	**100.0%**	**$25,047**	**100.0%**	**$15,289**	**100.0%**	**$13,009**	**100.0%**
APPLICATIONS OF FUNDS										
Dividends	$ 2,287	11.6%	$ 2,181	11.3%	$ 1,992	8.0%	$ 2,049	13.4%	$ 1,998	15.4%
Capital expenditures	8,991	45.5	6,437	33.5	5,986	23.9	6,500	42.5	6,400	49.2
Additions to working capital	594	3.0	2,879	15.0	−567	−2.3	49	0.3	−436	−3.4
Reduction of long-term debt	3,164	16.0	2,564	13.3	7,669	30.6	2,555	16.7	2,529	19.4
Other applications	4,736	23.9	5,184	26.9	9,966	39.8	4,137	27.1	2,518	19.4
TOTAL	**$19,772**	**100.0%**	**$19,245**	**100.0%**	**$25,047**	**100.0%**	**$15,289**	**100.0%**	**$13,009**	**100.0%**

Note: Data are totals for 12 major chemical producers: American Cyanamid, Dow Chemical, Du Pont, Ethyl (excludes insurance business), W. R. Grace, Hercules, Monsanto, Olin, Pennwalt, Quantum Chemical, Rohm & Haas, and Union Carbide. **Sources:** Company annual reports

Dow Chemical netted more than $2.4 billion last year. That's more than any U.S. chemical company had ever earned before. It is not surprising, then, that a satisfied president Frank Popoff told company shareholders in Dow's annual report this spring that in 1988 "fundamentals in the chemical industry were the strongest in years."

Dow, to be sure, is not the only U.S. chemical producer to report rosy results for 1988. As the following compilation of the financial results of major companies in the industry clearly demonstrates, it was the exception that did not rack up sharply improved returns both on sales and stockholders' equity.

Some of the most sparkling results, moreover, were from some of the newest names in the industry—companies like Arco Chemical, Aristech, Georgia Gulf, Himont, and Vista Chemical. For them, all of whom have major stakes in commodity chemical product lines no longer in favor with many of their older competitors, the combination of vigorous demand, surging selling prices, and streamlined operations has proved extraordinarily profitable. Even IMC Fertilizer Group, a company formed in early 1988 as a spinoff of International Minerals & Chemical's long lackluster fertilizer business, reported a "memorable and rewarding initial year" in its first annual report last year, with earnings of $112 million, more than four times what its business netted the year before.

Explanation of table headings

Year. Data are for calendar year unless otherwise indicated.

Net sales. Gross sales, less discounts, allowances, and returns; generally excludes excise taxes and other operating income or revenues.

Net income. Net sales and other income, less operating costs, nonoperating charges, depreciation, depletion, interest expense, deferred charges, minority interest in income, and taxes. Nonrecurring or extraordinary credits and charges have been excluded in most cases, but these items are indicated by a footnote.

Total assets. Sum at year's end of current assets, investments, prepaid expenses, net plant and equipment, and other tangible assets. Excludes insofar as possible intangible assets including goodwill, value of patents and trademarks, and the like.

Current ratio. The ratio of current assets (cash, marketable securities, receivables, and inventories but excluding prepaid expenses) to total current liabilities.

Net plant and equipment. Value at year's end of fixed assets, less accumulated depreciation, amortization, and depletion.

Capital expenditures. Total spending during the year for new fixed assets, such as plant, equipment, and land, and for replacement and modernization of facilities.

Net worth. Equity at year's end of preferred and common stock holders, including value of capital stock, capital and earned surplus, and surplus reserves, as well as contingency and miscellaneous reserves for which no definite purpose is stated. Intangible assets are deducted insofar as possible.

Net income (breakdown). **Percent of sales:** net income divided by net sales. **Percent of net worth:** net income divided by tangible net worth. **Dollars per share:** net income, less preferred dividends, divided by the number of shares of common stock outstanding. All figures are adjusted for stock splits, but no adjustment has been made for earlier years as a result of stock dividends or for dilution that might result from the conversion of preferred stock or debt to common stock or the exercise of stock options outstanding.

Dividends per share. Cash dividends paid (or declared) on each share of common stock; excludes the value of stock dividends, which are indicated by a footnote.

Dividend yield. Dividends per share divided by the average of the high and low prices of the common stock during the calendar year.

Stock price range. High-low market prices of common stock during the calendar year, adjusted for stock splits but not for stock dividends.

Price-earnings ratio. Average of the high and low prices of the common stock during the calendar year divided by net income per share.

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME			Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
								% of sales	% of net worth	$ per share				
					Money figures in thousands of dollars unless otherwise indicated									
CHEMICALS														
Air Products & Chemicals														
1988[a]	$2,431,866	$213,747	$2,962,295	1.1	$2,061,642	$409,433	$1,235,027	8.8%	17.3%	$3.90	$1.10	2.4%	$53⅜–36½	11.5
1987[a]	2,132,176	159,688[b]	2,695,625	1.2	1,920,520	322,765	1,140,512	7.5	14.0	2.83[b]	0.90	2.2	53⅞–29	14.6
1986[a]	1,982,134	4,735[c]	2,700,151	1.4	1,829,122	366,563	1,094,562	0.2	0.4	0.08[c]	0.77	2.2	41⅝–29⅛	422.2
1985[a]	1,829,588	143,484[d]	2,539,545	1.1	1,782,267	392,176	1,109,068	7.8	12.9	2.38[d]	0.635	2.3	34⅛–22¼	11.9
American Cyanamid Co.														
1988	$4,592,000	$305,600	$4,332,200	1.4	$1,556,800	$373,800	$1,801,100	6.7%	17.0%	$3.41	$1.16	2.4%	$ 56–41⅞	14.4
1987	4,166,100	264,000[e]	3,878,400	1.5	1,391,900	268,100	1,622,400	6.3	16.3	2.89	1.025	2.4	57–29	14.9
1986	3,815,900	202,500	3,482,400	1.7	1,267,700	262,500	1,536,000	5.3	13.2	2.18	0.95	2.6	44⅞–27⅛	16.5
1985	3,536,100	120,200[f]	3,383,400	2.0	1,126,900	202,600	1,623,000	3.4	7.4	1.25[f]	0.95	3.5	29⅜–24	21.4
Arco Chemical Co.														
1988	$2,700,000	$494,000	$2,548,000	1.8	$1,078,000	$199,000	$1,375,000	18.3%	35.9%	$5.00	$0.85	2.8%	$ 38–23¼	6.1
1987[g]	1,952,000	257,000	2,534,000	1.3	984,000	295,000	1,116,000	13.2	23.0	2.58[h]	0.20	0.7	38¾–17	10.8
1986	1,541,000	143,000	1,450,000	2.6	752,000	167,000	952,000[i]	9.3	15.0	1.44[h]	—	—	—	—
1985	1,589,000	89,000	1,278,000	—	—	86,000	879,000[i]	5.6	10.1	—	—	—	—	—
Aristech Chemical Corp.														
1988	$1,065,200	$164,500[j]	$ 676,100	1.8	$ 422,500	$ 55,800	$ 410,400	15.4%	40.1%	$6.62	$0.86	3.0%	$ 36–22¼	4.4
1987	918,800	69,700	551,200	2.5	299,700	43,700	362,700	7.6	19.2	2.71	0.54	1.9	39–16¾	10.3
1986[k]	750,800	47,600	476,100	1.9	286,300	15,600	309,700	6.3	15.4	1.70[h]	0.00	0.0	18⅝–17¾	10.7
1985	789,100	20,500	452,400	2.5	303,200	17,900	262,900[l]	2.6	7.8	0.65[h]	—	—	—	—

a Fiscal year ends Sept. 30. **b** Excludes extraordinary net loss on extinguishment of debt of $4.1 million ($0.07 per share). **c** Includes special charge for writedown of assets, revaluation of South African investment, and staff reduction program of $132.2 million ($2.25 per share) and for loss of investment tax credits of $7 million ($0.13 per share). **d** Includes special charges, before taxes, of $300,000. **e** From continuing operations, excludes net income from discontinued operations of $11.6 million ($0.13 per share) but includes gain on sale of fragrance and skin care businesses, before taxes, of $12.0 million ($0.13 per share). **f** From continuing operations, excludes net income and gain on sale of Formica Brand Products Group of $8.9 million ($0.09 per share). **g** Arco Chemical, previously a subsidiary of Atlantic Richfield Co., became an independent, publicly owned company on Oct. 5, 1987. **h** Pro forma. **i** Atlantic Richfield equity investment. **j** Excludes special credit for cumulative effect on prior years in accounting for income taxes of $23.7 million ($0.95 per share) but includes gain on sale of Houston, Tex., plant, before taxes, of $23.9 million. **k** Aristech Chemical, previously the USS Chemicals division of USX Corp., became an independent, publicly owned company on Dec. 4, 1986. **l** USX Corp. equity investment.

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME			Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
								% of sales	% of net worth	$ per share				
						Money figures in thousands of dollars unless otherwise indicated								
Betz Laboratories														
1988	$ 447,580	$ 48,385	$ 307,862	1.9	$ 174,970	$ 43,505	$ 219,901	10.8%	22.0%	$ 3.15	$1.60	3.4%	$ 52½–41¼	14.9
1987	385,868	40,634	275,664	1.7	153,200	25,428	193,959	10.5	20.9	2.59	1.46	3.1	58¼–35	18.0
1986	344,377	35,544	267,681	2.3	144,053	22,750	202,104	10.3	17.6	2.23	1.36	3.4	44¾–35	17.9
1985	319,381	36,792	253,704	2.2	137,255	27,030	194,793	11.5	18.9	2.33	1.26	3.7	38¼–30¼	14.7
Cabot Corp														
1988[a]	$ 1,676,588	$ 61,175[b]	$ 1,530,186	1.3	$ 838,909	$ 169,957	$ 594,295	3.6%	10.3%	$ 2.27[b]	$1.15	3.2%	$ 41¾–29⅛	15.6
1987[a]	1,424,041	39,235[c]	1,447,001	1.2	794,470	81,087	574,610	2.8	6.8	1.42[c]	0.92	2.5	49¼–25¼	26.2
1986[a]	1,309,915	73,061[d]	1,490,759	2.0	642,137	72,551	572,145	5.6	12.8	2.56[d]	0.92	3.1	35⅜–23⅜	11.5
1985[a]	1,407,516	71,290[e]	1,573,086	1.9	623,211	141,559	604,085	5.1	11.8	2.22[e]	0.92	3.4	33¾–20½	12.2
Chemed Corp														
1988	$ 500,647	$ 20,649[f]	$ 268,496	1.7	$ 61,102	$ 14,641	$ 57,061	4.1%	36.2%	$ 2.23[f]	$1.72	5.1%	$ 38–29¾	15.2
1987	391,004	20,362	220,549	1.5	48,545	8,893	69,944	5.2	29.1	2.28	1.60	4.5	44⅛–26⅜	15.5
1986	359,476	6,830[g]	229,316	1.6	46,554	9,385	75,339	1.9	9.1	0.76[g]	1.56	4.4	40–30⅛	46.1
1985	372,677	21,858	197,615	1.7	42,092	7,874	58,234	6.6	37.5	2.49	1.52	5.1	33⅝–25¾	11.9
Crompton & Knowles Corp														
1988	$ 289,787	$ 16,845[h]	$ 177,204	1.5	$ 43,685	$ 7,050	$ 53,483	5.8%	31.5%	$ 2.85[h]	$0.86	3.1%	$ 35¾–19⅞	9.8
1987	237,469	11,750	127,689	2.2	29,085	3,632	68,265	4.9	17.2	1.95	0.67	2.8	30¼–18	12.4
1986	213,242	8,923[i]	126,881	2.2	28,511	3,514	60,565	4.2	14.5	1.32[i]	0.63	4.0	19⅝–12¼	12.0
1985	231,225	7,575	120,076	2.5	30,376	3,362	63,839	3.3	11.9	1.10	0.60	5.3	13⅝–9¼	10.3
Dow Chemical Co.														
1988	$16,682,000	$2,410,000[j]	$15,548,000	1.9	$ 6,576,000	$1,267,000	$ 6,564,000	14.4%	36.7%	$12.82[j]	$2.45	2.9%	$ 94–76¾	6.7
1987	13,377,000	1,245,000[k]	13,871,000	1.7	5,551,000	995,000	5,284,000	9.3	23.6	6.50[k]	2.10	2.5	109⅝–58¾	13.0
1986	11,113,000	741,000[l]	11,939,000	1.6	5,347,000	890,000	4,865,000	6.7	15.2	3.87[l]	1.85	3.6	61¾–39⅞	13.1
1985	10,500,000	58,000	11,565,000	1.5	5,127,000	806,000	4,527,000	0.6	1.3	0.31	1.80	5.2	41⅞–27	111.1
E. I. du Pont de Nemours & Co.														
1988	$32,917,000	$2,190,000	$30,159,000	1.5	$17,221,000	$4,001,000	$15,020,000	6.7%	14.6%	$ 9.11	$3.70	4.4%	$ 92⅞–75¾	9.3
1987	30,468,000	1,786,000	27,604,000	1.5	15,854,000	3,035,000	13,639,000	5.9	13.1	7.39	3.30	3.2	131–75	13.9
1986	27,148,000	1,538,000	26,083,000	1.5	15,697,000	2,737,000	12,724,000	5.7	12.1	6.35	3.05	4.0	92½–59½	12.0
1985	29,483,000	1,118,000	25,108,000	1.6	15,195,000	3,046,000	12,627,000	3.8	8.9	4.61	3.00	5.1	69⅜–47⅝	12.7
Ethyl Corp.														
1988	$ 2,011,487	$ 231,016	$ 5,107,817[m]	2.5	$ 719,551	$ 151,116	$ 986,289	11.5%	23.4%	$ 1.91	$0.45	2.2%	$ 24⅛–17¼	10.8
1987	1,720,338	193,319	1,875,614	2.2	674,075	138,481	852,799	11.2	22.7	1.57	0.40	1.7	32¼–15	15.0
1986	1,579,254	177,734	1,567,825	2.1	594,238	133,700	895,790	11.3	19.8	1.40	0.335	1.8	22¾–13½	12.9
1985	1,547,034	117,146[n]	1,509,988	2.0	557,256	89,512	754,853	7.6	15.5	0.92	0.285	2.5	15¼–7⅞	12.6
Ferro Corp														
1988	$ 1,008,990	$ 46,620	$ 574,943	1.7	$ 197,222	$ 49,308	$ 282,137	4.6%	16.5%	$ 3.40	$0.70	2.3%	$ 40¾–21	9.1
1987	871,088	31,687	521,314	1.7	171,889	30,674	249,039	3.6	12.7	2.30	0.67	2.7	31¼–17½	10.6
1986	725,241	24,082	443,801	1.9	153,712	23,162	217,750	3.3	11.1	1.77	0.60	3.4	20⅝–15⅛	10.1
1985	651,071	11,163[o]	391,133	2.0	145,651	26,451	193,850	1.7	5.6	0.83[o]	0.60	3.9	18½–12⅛	18.4
First Mississippi Corp														
1988[p]	$ 318,086	$ 32,475	$ 325,339	1.5	$ 166,966	$ 60,381	$ 181,447	10.2%	17.9%	$ 1.61	$0.24	1.6%	$ 18⅜–12	9.4
1987[p]	278,946	18,610	276,638	1.8	152,671	19,527	138,882	6.7	13.4	0.93	0.24	1.9	19⅛–6½	13.8
1986[p]	268,898	(28,110)[q]	287,562	1.6	155,266	31,635	125,521	—	—	(1.42)[q]	0.24	3.6	8⅛–5¼	—
1985[p]	273,185	18,239[r]	379,587	1.5	234,574	63,257	165,339	6.7	10.1	0.90[r]	0.24	2.6	11⅝–6⅝	10.1
Georgia Gulf Corp														
1988	$ 1,060,612	$ 193,604	$ 437,083	2.0	$ 169,256	$ 25,062	$ 235,839	18.3%	82.1%	$ 6.75	$0.65	2.0%	$ 39⅞–24⅜	4.8
1987	707,453	91,736[s]	308,609	1.7	119,984	9,931	142,546	13.0	64.4	3.15[s]	0.20	0.9	34½–9⅞	7.1
1986	583,255	39,123	264,632	2.0	119,116	7,428	77,956	6.7	50.2	1.20	0.00	0.0	10–9¾	8.2
1985	613,537	36,431	292,142	1.1	135,007	6,177	36,289	5.9	100.4	1.11	0.00	—	—	—
B. F. Goodrich Co.														
1988	$ 2,416,700	$ 209,900[t]	$ 1,987,300	1.9	$ 934,400	$ 180,500	$ 1,080,200	8.7%	19.4%	$ 7.99[t]	$1.72	3.5%	$ 60¾–37½	6.1
1987	2,168,000	83,900[u]	1,905,800	1.4	898,200	142,600	972,600	3.9	8.6	3.17[u]	1.56	3.4	65–27¾	14.6
1986	2,553,300	12,900[v]	1,786,700	1.4	865,200	144,000	799,200	0.5	1.6	0.46[v]	1.56	3.9	47⅞–32⅛	87.0
1985	3,200,500	(316,800)[q,w]	2,227,400	1.1	1,043,900	202,300	675,800	—	—	(14.11)[q,w]	1.56	5.0	35–25¾	—

a Fiscal year ends Sept. 30. **b** Excludes extraordinary net charge on early retirement of debt of $800,000 ($0.03 per share). **c** Excludes extraordinary net charge on early retirement of debt of $10.5 million ($0.38 per share). **d** Excludes extraordinary net charge on early retirement of debt of $2.0 million ($0.07 per share). **e** From continuing operations; excludes net loss from discontinued operations of $12.7 million ($0.39 per share) and provision for net loss on disposal of discontinued operations of $145.0 million ($4.53 per share). **f** From continuing operations; excludes net income from discontinued operations, extraordinary gain on termination of pension plan, and cumulative effect of changes in accounting principles of $3.5 million ($0.37 per share). **g** From continuing operations; excludes net income and gain on sale of discontinued Vestal Laboratories operations of $30.0 million ($3.36 per share) and extraordinary gain on termination of pension plan of $811,000 ($0.09 per share). **h** From continuing operations; excludes net loss from operations and on disposal of maintenance chemical business of $1.5 million ($0.25 per share). **i** From continuing operations; excludes net income and charge for discontinued Kem operations of $7.9 million ($1.24 per share). **j** Excludes net loss on early extinguishment of debt of $12 million ($0.06 per share). **k** Excludes net loss on early extinguishment of debt of $5 million ($0.03 per share). **l** Excludes net loss on early extinguishment of debt of $9 million ($0.05 per share). **m** Includes total assets of insurance business, previously carried as net investment in the business. **n** Includes net charge for plant shutdown and write-off costs of $20.0 million. **o** Excludes net loss on sale of Productol Chemical division of $2.3 million ($0.17 per share). **p** Fiscal year ends June 30. **q** Net loss. **r** Excludes net gain on disposal of FirstMiss subsidiary of $900,000 ($0.04 per share). **s** Excludes extraordinary net charge on retirement of debt of $9.9 million ($0.34 per share). **t** From continuing operations; excludes net loss from discontinued operations of $16.9 million ($0.68 per share) and net gain from cumulative effect of change in accounting for income taxes of $2.7 million ($0.11 per share). **u** From continuing operations; excludes net loss from discontinued operations of $4.7 million ($0.20 per share) and extraordinary net income of $25.8 million ($1.09 per share). **v** Excludes extraordinary net income of $19.8 million ($0.86 per share). **w** From continuing operations; excludes net loss from discontinued operations of $37.8 million ($1.68 per share).

2 Finances of the U.S. Chemical Industry

(Money figures in thousands of dollars unless otherwise indicated)

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME			Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
								% of sales	% of net worth	$ per share				
W. R. Grace & Co.														
1988	$5,786,100	$192,000[a]	$5,095,200	1.3	$2,028,300	$418,100	$1,336,000	3.3%	14.4%	$2.26[a]	$1.40	5.2%	$29⅞-23½	11.8
1987	4,515,400	141,900[b]	4,361,500	1.4	1,701,000	242,500	1,351,200	3.1	10.5	1.67[b]	1.40	5.0	37⅜-19⅛	16.9
1986	3,725,700	(375,400)[c,d]	3,993,000	1.3	1,579,000	199,100	1,204,400	—	—	(4.47)[c,d]	1.40	5.3	30⅜-22⅝	—
1985	5,193,000	127,800[e]	5,287,800	1.9	2,596,000	348,000	2,271,400	2.5	5.6	1.22[e]	1.40	6.6	24¾-17¾	17.3
Great Lakes Chemical Corp.														
1988	$ 557,770	$103,288	$ 612,242	1.7	$ 234,405	$ 47,017	$ 430,629	18.5%	24.0	$5.93	$0.68	1.2%	$65⅞-48⅝	9.7
1987	478,386	55,536	523,365	1.8	218,403	35,186	338,880	11.6	16.4	3.34	0.60	1.1	77-35⅞	16.9
1986	300,329	26,817	447,840	2.3	209,425	18,327	172,538	8.9	15.5	1.79	0.52	1.4	44½-30⅞	21.1
1985	276,932	28,818	314,423	2.2	137,710	21,344	186,718	10.4	15.4	1.93	0.44	1.2	44¼-31¼	19.6
Hercules														
1988	$2,802,072	$120,435	$3,325,294	2.8	$1,164,102	$251,043	$2,044,533	4.3%	5.9%	$2.55	$2.00	4.1%	$ 54-42⅝	18.9
1987	2,693,003	208,000[f]	3,492,077	3.6	1,075,389	205,037	2,189,867	7.7	9.5	4.02[f]	1.64	3.2	73½-40	14.1
1986	2,615,110	206,200[g]	2,914,319	2.6	1,152,141	256,913	1,703,151	7.8	12.1	3.66[g]	1.72	3.5	60-37	13.3
1985	2,587,213	133,161[h]	2,658,822	2.5	1,000,212	234,240	1,474,201	5.1	9.0	2.40	1.60	4.5	40¾-31⅛	15.0
Himont														
1988[i]	$1,710,780	$372,897	$1,882,258	3.4	$515,029	$168,306	$1,335,385	21.8%	27.9%	$5.71	$1.20	3.2%	$ 47-29	6.7
1987[i,j]	1,165,031	226,906	1,487,040	4.6	393,658	85,074	1,046,845	19.5	21.7	3.77	0.34	0.9	54¼-23	10.2
1986[i]	980,909	97,334	910,032	1.6	379,225	115,250	450,622	9.9	21.6	2.17	3.65[k]	—	—	—
1985[i]	910,503	52,800	689,291	2.5	298,012	52,569	383,457	5.8	13.8	1.38	0.34	—	—	—
IMC Fertilizer Group														
1988[l,m]	$1,085,600	$111,700	$1,472,100	1.6	$780,000	$26,300	$ 676,100	10.3%	16.5%	$3.88	$0.37	1.1%	$45⅛-22½	8.7
1987[l]	876,200	26,600	1,332,200	1.7	841,600	110,400	1,004,300	3.0	2.6	0.10	—	—	—	—
1986[l]	866,000	(34,700)[d]	1,242,500	2.2	—	52,000	1,028,800	—	—	—	—	—	—	—
1985[l]	1,060,900	83,900	1,347,200	2.3	—	59,500	1,124,800	7.9	7.5	—	—	—	—	—
International Flavors & Fragrances														
1988	$ 839,545	$128,684	$ 882,333	5.0	$ 228,152	$ 40,812	$ 695,433	15.3%	18.5%	$3.40	$1.60	3.3%	$54½-43⅛	14.4
1987	745,861	107,017	874,554	4.2	219,305	36,946	659,908	14.3	16.2	2.83	1.24	2.6	57¾-37¼	16.8
1986	520,679	85,683	672,616	4.6	186,891	26,771	521,475	13.8	16.4	2.29	1.16	2.8	48⅞-34½	18.2
1985	501,046	69,698	559,855	4.2	159,298	22,134	426,986	13.9	16.3	1.89	1.12	3.4	40-26	17.5
International Minerals & Chemical Corp.														
1988[l]	$1,470,600	$103,900[n]	$1,588,900	2.0	$ 627,400	$ 81,200	$ 822,800	7.1%	12.6%	$3.30[n]	$1.00	2.3%	$51½-37¼	13.4
1987[l]	1,637,500	14,600[o]	2,242,400	1.4	2,292,500	62,500	877,200	0.9	1.7	0.08[o]	1.00	2.5	53-26½	496.9
1986[l]	1,177,700	(79,600)[d,p]	2,225,200	2.2	2,170,700	93,900	792,400	—	—	(2.96)[d,p]	1.80	5.9	36¼-25	—
1985[l]	1,627,300	119,600	1,957,200	2.0	2,144,300	116,000	1,092,000	7.3	11.0	4.39	2.60	6.6	44-34¼	8.9
Lawter International														
1988	$ 125,818	$ 20,851	$ 125,210	3.7	$ 24,546	$ 4,524	$ 79,521	16.6%	26.2%	$0.88	$0.52	4.2%	$14⅛-10¾	14.1
1987	112,018	16,701	109,917	4.3	22,603	1,528	69,458	14.9	24.0	0.71	0.42	3.5	15⅝-8½	17.0
1986	103,515	12,945	93,392	3.7	22,447	1,613	55,191	12.5	23.5	0.56	0.42	3.9	13-8⅝	19.5
1985	96,769	(5,413)[d,q]	84,039	3.4	22,702	3,179	47,588	—	—	(0.23)[d,q]	0.42	4.7	10⅛-7¾	—
Loctite Corp.														
1988[l]	$ 416,880	$ 41,850	$ 328,833	2.4	$ 73,008	$ 14,466	$ 187,100	10.0%	22.4%	$2.32	$0.61	1.8%	$ 39-27	14.2
1987[l]	337,802	30,665	289,367	1.9	70,802	15,470	167,561	9.1	18.3	1.69	0.47	1.7	36-19	16.3
1986[l]	266,788	23,173	240,665	2.2	57,711	9,299	150,163	8.7	15.4	1.28	0.41	2.0	24⅞-16⅝	16.2
1985[l]	231,479	20,443	215,482	1.9	49,793	11,278	121,918	8.8	16.8	1.12	0.40	2.5	18½-13½	14.3
Lubrizol Corp.														
1988	$1,117,493	$131,206[r]	$ 970,671	3.0	$ 298,670	$ 54,611	$ 664,308	11.7%	19.8%	$3.40[r]	$1.30	3.6%	$42⅜-30	10.6
1987	1,013,430	81,335	939,378	3.0	297,573	42,040	621,633	8.0	13.1	2.06	1.22	3.6	41¾-25¼	16.3
1986	976,776	78,185	877,907	2.7	289,078	40,460	572,679	8.0	13.7	1.97	1.17	3.9	35⅛-25⅝	15.4
1985	903,403	60,224	854,445	2.4	290,298	39,498	519,298	6.7	11.6	1.49	1.16	4.8	28⅞-19¾	16.3
Monsanto Co.														
1988	$8,293,000	$591,000	$6,671,000	1.3	$3,146,000	$590,000	$2,010,000	7.1%	29.4%	$8.27	$2.95	3.6%	$92⅜-73½	10.0
1987	7,639,000	436,000	6,502,000	1.4	3,076,000	505,000	1,948,000	5.7	22.4	5.63	2.75	3.5	100¼-57	14.0
1986	6,879,000	433,000	6,125,000	1.4	2,913,000	520,000	1,637,000	6.3	26.5	5.55	2.575	4.1	81½-44¾	11.4
1985	6,747,000	(128,000)[d,s]	6,678,000	1.1	3,034,000	645,000	1,208,000	—	—	(1.67)[d,s]	2.45	5.1	55⅜-40⅝	—
Morton Thiokol														
1988[l]	$2,316,400	$159,400[t]	$1,670,800	1.8	$ 760,300	$163,000	$ 815,900	6.9%	19.5%	$3.33[t]	$0.82	2.0%	$ 46-35⅝	12.3
1987[l]	1,987,300	138,000	1,426,400	1.5	655,900	130,400	700,400	6.9	19.7	2.90	0.745	1.7	54¾-31	14.8
1986[l]	1,949,900	132,900	1,225,000	1.7	593,900	95,700	629,900	6.8	21.1	2.80	0.685	1.9	42½-30	12.9
1985[l]	1,832,300	119,500[u]	1,173,900	1.8	560,700	117,000	510,500	6.5	23.4	2.44[u]	0.63	1.9	40½-26	13.6

a From continuing operations; excludes net income from discontinued operations and gain from cumulative effect of accounting change of $41.6 million ($0.49 per share). **b** From continuing operations; excludes net income from discontinued operations of $18.6 million ($0.22 per share) and tax benefit of operating loss carry-forward of $12.6 million ($0.14 per share). **c** From continuing operations; includes asset write-downs and reserves, before taxes, of $368.8 million but excludes net loss from discontinued operations of $96.9 million ($1.15 per share). **d** Net loss. **e** From continuing operations; excludes net income from discontinued retail operations of $19.1 million ($0.18 per share). **f** Excludes net gain on disposal of Himont and other net gains and charges of $613.7 million ($10.72 per share). **g** Excludes nonrecurring net gains from sale of investments and businesses and nonrecurring net costs of $20.5 million ($0.36 per share). **h** Includes pretax gain on disposal of assets of $16.4 million. **i** Fiscal year ends Oct. 31. **j** Himont, previously jointly owned by Hercules and Montedison, became a publicly owned company on Feb. 20. **k** Includes distribution to Hercules and Montedison of $2.36 per share. **l** Fiscal year ends June 30. **m** IMC Fertilizer Group, previously the fertilizer business group of International Minerals & Chemical Corp., became an independent, privately owned company on Feb. 2. **n** From continuing operations; excludes net loss on disposal of discontinued operations of $5.0 million ($0.19 per share) and extraordinary net credit of $16.2 million ($0.55 per share). **o** From continuing operations; excludes net income on disposal of discontinued operations of $11.3 million ($0.41 per share) and extraordinary net charge of $4.8 million ($0.18 per share). **p** From continuing operations; excludes net loss from and net provision for loss on disposal of discontinued gas and oil and industrial products operations of $137.4 million ($5.08 per share). **q** Includes one-time tax provision for future repatriation of foreign earnings of $14.0 million ($0.60 per share). **r** Includes credit for patent litigation settlement, before taxes, of $81.2 million but excludes net credit for cumulative effect of change in accounting for income taxes of $8.8 million ($0.22 per share). **s** Includes special charge for restructuring costs, before taxes, of $557 million but excludes net gain from repayment of debt of $30 million ($0.40 per share). **t** Excludes net charge for cumulative effect of change in accounting for income taxes of $14.1 million ($0.29 per share). **u** From continuing operations; excludes net income from discontinued Texsize Division operations of $3.3 million ($0.06 per share) and net gain on sale of the division of $75.1 million ($1.51 per share).

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME % of sales	NET INCOME % of net worth	NET INCOME $ per share	Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
(Money figures in thousands of dollars unless otherwise indicated)														
NL Industries														
1988[a]	$1,007,036	$134,236[b]	$ 836,941	1.4	$ 344,020	$ 70,624	$ 150,951	13.3%	88.9%	$ 2.02[b]	$0.20[c]	3.1%	$ 7¾–5¼[c]	—
1987[a]	859,267	87,866[d]	1,092,483	1.5	315,907	73,318	406,220	10.2	21.6	1.31[d]	0.20[c]	2.6	11–4¼[c]	—
1986	549,314	(382,197)[e,f]	1,149,950	1.1	349,854	24,499	444,901	—	—	(6.31)[e,f]	0.17	1.7	16⅛–3⅜	—
1985	1,422,995	23,933[g]	1,596,537	1.4	719,717	93,126	810,556	1.7	3.0	0.34[g]	0.20	1.7	14½–9⅛	34.7
Nalco Chemical Co.														
1988	$ 994,150	$105,971	$ 838,857	2.0	$ 311,200	$ 61,578	$ 433,550	10.7%	24.4%	$ 2.70	$1.29	3.6%	$ 39⅞–31¼	13.2
1987	841,875	80,254	696,360	1.7	304,084	57,232	396,297	9.5	20.3	2.03	1.20	3.5	45½–24	17.1
1986	736,074	63,672	536,916	1.7	280,195	63,636	358,023	8.7	17.8	1.62	1.20	4.4	31¼–23½	16.9
1985	682,333	73,332	492,998	1.8	247,912	59,905	335,685	10.7	21.8	1.87	1.20	4.8	28⅜–22	13.5
Olin Corp.														
1988	$2,308,000	$ 98,000	$1,799,000	1.3	$ 801,000	$147,000	$ 542,000	4.2%	18.1%	$ 4.63	$1.70	3.4%	$ 60–40	10.8
1987	1,930,000	78,000	1,583,000	1.7	727,000	115,000	598,000	4.0	13.0	3.38	1.60	3.6	56¼–32⅝	13.1
1986	1,707,261	75,226	1,464,830	1.5	719,686	127,935	574,290	4.4	13.1	3.36	1.525	3.5	53¼–34⅝	13.1
1985	1,751,106	(190,308)[e,h]	1,516,096	1.6	718,371	154,499	604,844	—	—	(8.28)[e,h]	1.50	4.5	38–28⅜	—
Pennwalt Corp.														
1988	$1,023,640	$ 48,256[i]	$ 917,906	1.1	$ 357,959	$ 46,694	$ 194,255	4.7%	24.8%	$ 3.87	$2.40	3.2%	$106¾–43¼	19.4
1987	1,142,750	53,803[j]	993,626	1.9	432,029	54,877	427,110	4.7	12.6	4.12[j]	2.25	4.4	68¼–34¾	12.5
1986	1,107,564	51,947	962,252	2.1	436,282	54,379	465,369	4.7	11.2	3.64	2.20	4.4	59–40¾	13.7
1985	1,013,308	11,216[k]	937,672	1.5	433,867	89,691	445,020	1.1	2.5	0.05[k]	2.20	5.6	44½–34	785.0
Quantum Chemical Corp.														
1988	$2,921,900	$360,100[l]	$2,881,300	0.7	$1,308,600	$333,500	$ (433,400)[m]	12.3%	—	$13.71	$2.40	2.8%	$108¼–65½	6.3
1987	2,566,800	143,600[n]	2,519,300	1.3	1,380,200	154,200	983,500	5.6	14.6%	4.38[n]	2.20	3.4	88–42½	14.9
1986	1,729,600	55,100[o]	2,844,200	1.0	1,393,800	101,600	944,500	3.2	5.8	1.54[o]	2.20	5.7	47⅝–30	25.3
1985	2,289,000	77,000[p]	1,948,000	1.5	899,300	76,200	930,300	3.4	8.3	2.27[p]	2.20	7.2	37½–23⅝	13.5
Rohm & Haas Co.														
1988	$2,535,000	$230,000	$2,148,000	1.7	$ 935,000	$338,000	$1,113,000	9.1%	20.7%	$ 3.46	$1.02	3.1%	$ 37½–28	9.5
1987	2,203,000	195,000[q]	1,882,000	1.9	730,000	222,000	981,000	8.9	19.9	2.85[q]	0.86	2.2	53¼–24	13.6
1986	2,067,000	138,000[r]	1,756,000	2.0	648,000	179,000	916,000	6.7	15.1	2.01[r]	0.78	2.5	38¾–23⅞	15.6
1985	2,051,000	141,000[s]	1,655,000	2.0	581,000	159,000	857,000	6.9	16.5	2.01[s]	0.70	3.1	26⅛–18⅝	11.1
Sigma-Aldrich Corp.														
1988	$ 375,282	$ 56,477	$ 359,671	2.5	$ 119,518	$ 35,605	$ 243,906	15.0%	23.2%	$ 2.29	$0.33	0.7%	$ 51¼–39¾	19.9
1987	304,858	41,889	285,343	2.9	96,975	20,616	196,012	13.7	21.4	1.70	0.29	0.7	50⅝–30¼	23.8
1986	253,097	33,958	244,875	2.5	86,111	35,461	155,689	13.4	21.8	1.38	0.25	0.7	40¼–26¾	24.3
1985	214,848	28,855	186,552	3.4	57,771	17,386	126,306	13.4	22.9	1.13	0.21	0.9	28⅜–17⅛	20.1
Stepan Co.														
1988	$ 333,033	$ 13,428	$ 185,601	1.6	$ 104,697	$ 20,442	$ 66,790	4.0%	20.1%	$ 2.39	$0.475	2.1%	$ 25⅝–19¾	9.5
1987	288,935	10,959	172,726	1.6	98,994	25,705	59,936	3.8	18.3	1.83	0.415	2.0	26¾–14½	11.2
1986	259,787	7,513	152,794	1.5	85,607	14,322	55,029	2.9	13.6	1.265	0.37	2.6	17⅝–10⅜	11.3
1985	235,919	5,471	139,307	1.5	82,796	19,189	49,575	2.3	11.0	0.945	0.345	3.5	11⅝–8⅛	10.5
Union Carbide Corp.														
1988	$8,324,000	$662,000	$8,389,000	1.1	$4,416,000	$671,000	$1,784,000	8.0%	37.1%	$ 4.88	$1.15	5.1%	$ 28⅜–17	4.6
1987	6,914,000	232,000	7,820,000	1.3	4,344,000	502,000	1,175,000	3.4	19.7	1.76	1.50	6.2	32½–15½	13.6
1986	6,244,000	130,000[t]	7,496,000	1.2	4,379,000	524,000	930,000	2.1	14.0	1.25[t]	1.50	5.8	33⅛–18¾	20.8
1985[u]	6,596,000	(38,000)[e]	8,461,000	1.3	4,927,000	649,000	519,000	—	—	(0.38)[e]	1.13	6.1	24¾–12	—
Vista Chemical Corp.														
1988[v]	$ 781,351	$123,917[w]	$ 500,643	1.6	$ 275,544	$ 48,082	$ 119,438	15.9%	103.8%	$ 7.10[w]	$0.35	0.1%	$ 61–39	7.0
1987[v]	608,887	(1,762)[e,x]	474,265	1.5	266,250	20,889	134,686	—	—	(0.13)[e,x]	0.05	0.1	55⅛–18⅝	—
1986[v]	550,097	30,212[y]	453,418	1.8	272,699	15,792	60,808	5.5	49.7	1.73[y]	0.00	0.0	18¾–17	10.3
1985[v]	521,313	11,917	454,688	1.9	282,946	10,284	23,281	2.3	51.2	0.68	0.00	0.0	—	—
Witco Corp.														
1988	$1,585,856	$ 71,621[z]	$1,096,219	3.1	$ 400,996	$ 72,059	$ 559,985	4.5%	12.8%	$ 3.05[z]	$1.39	4.0%	$ 38⅜–30⅝	11.3
1987	1,427,650	63,293	1,037,624	3.0	374,628	69,082	494,941	4.4	12.8	2.72	1.16	3.1	47⅜–26⅝	13.6
1986	1,355,018	65,215	804,086	2.4	367,789	60,102	449,783	4.8	14.5	2.93	1.05	3.2	40–26⅜	11.3
1985	1,448,929	56,774	794,368	2.3	360,950	71,093	399,486	3.9	14.2	2.57	0.99	4.0	27¾–22	9.7

a Restated to reflect restructuring and spin-off of petroleum services business on Dec. 22, 1988 (except as noted). **b** From continuing operations; excludes net income from discontinued operations of $21.5 million ($0.32 per share) and extraordinary net gain of $7.2 million ($0.11 per share). **c** Before restructuring. **d** From continuing operations; excludes net loss from discontinued operations of $107.8 million ($1.64 per share). **e** Net loss. **f** From continuing operations; excludes net income from discontinued operations of $58.0 million ($0.51 per share). **g** From continuing operations; excludes net loss on disposal of discontinued operations of $2.4 million ($0.04 per share). **h** From continuing operations; includes special charge for restructuring costs, before taxes, of $330.0 million but excludes net income and net gain on sale of Ecusta paper and film business of $25.0 million ($1.09 per share). **i** From continuing operations; excludes net loss and net gain on disposal of pharmaceutical and equipment operations of $130.4 million ($10.47 per share). **j** From continuing operations; excludes net income from discontinued equipment operations of $1.4 million ($0.10 per share). **k** From continuing operations; includes special charge for restructuring program, before taxes, of $38.6 million but excludes net loss from operations and on disposal of discontinued dental businesses of $30.9 million ($2.80 per share). **l** From continuing operations; excludes net income from discontinued oleochemical business of $22.6 million ($0.86 per share). **m** Deficit. **n** From continuing operations; excludes net income from discontinued spirits and wine operations of $108.0 million ($3.37 per share). **o** From continuing operations; excludes net income from discontinued spirits and wine operations of $20.5 million ($0.67 per share). **p** From continuing operations; excludes net income from discontinued insurance business of $200,000 ($0.01 per share). **q** Includes net gain on sales of assets of $5.0 million ($0.07 per share). **r** Includes net loss on disposal of assets of $9.2 million ($0.13 per share). **s** Includes net gain on disposal of assets of $4.6 million ($0.07 per share). **t** From continuing operations; excludes net income and net gain on disposal of discontinued operations of $569 million ($5.49 per share) and net charges for extraordinary items of $203 million ($1.96 per share). **u** Pro forma, after adjustment for repurchase of common stock, sale of consumer products businesses, special charges for restructuring program, and other special gains and losses. **v** Fiscal year ends Sept. 30. **w** Includes net gain associated with change in stock option plan of $1.5 million but excludes net loss on extinguishment of debt of $10.8 million ($0.62 per share). **x** Includes net charge associated with change in stock option plan of $55.4 million and net gain on sale of interest in Petroquimica Argentina of $5.1 million but excludes net loss on extinguishment of debt of $1.9 million ($0.12 per share). **y** Excludes net loss on extinguishment of debt of $1.4 million ($0.08 per share). **z** Excludes net gain for cumulative effect of accounting change of $20.3 million ($0.81 per share).

Finances of the U.S. Chemical Industry

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME % of sales	NET INCOME % of net worth	NET INCOME $ per share	Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
(Money figures in thousands of dollars unless otherwise indicated)														
[illegible]														
[illegible]														
1988	$4.936.991	$ 752.027	$4.825.113	1.4	$1.952.622	$521.196	$2,464.649	15.2%	30.5%	$3.33	$1.20	2.5%	$ 52⅜-42⅞	14.3
1987	4.387.876	632.559	4.385.737	1.3	1.741.557	432.736	2.093.453	14.4	30.2	2.78	1.00	1.9	67-40	19.3
1986	3.807.634	540.460	3.865.609	1.3	1.543.267	383.389	1.778.921	14.2	30.4	2.32	0.84	1.9	55-31⅝	18.7
1985	3.360.273	465.335	3.468.373	1.9	1.368.542	292.900	1.870.663	13.8	24.9	1.94	0.70	2.5	36-19⅞	14.4
[illegible]														
1988	$5.500.533	$ 932.184	$3.967.479	2.8	$1.309.314	$344.464	$2.332.475	16.9%	40.0%	$6.38	$3.60	4.6%	$ 84¼-71	12.2
1987	5.028.272	845.081	3.956.855	2.0	1.153.028	216.525	1.878.178	16.8	45.0	5.73	3.34	4.2	96¾-62	13.9
1986	4.926.512	778.824[a]	3.819.146	2.7	929.400	204.764	2.024.869	15.8	38.5	5.18[a]	3.10	4.0	94⅞-61¼	15.1
1985	4.684.742	717.140	3.201.746	3.3	859.414	179.347	2.098.293	15.3	34.2	4.70	2.90	5.0	66⅞-50⅛	12.4
[illegible]														
1988	$5.972.500	$ 829.000	$4.988.500	2.9	$1.249.100	$252.300	$3.345.800	13.9%	24.8%	$2.88	$1.68	4.0%	$ 46½-38⅛	14.7
1987	5.401.200	709.600[b]	4.549.400	2.8	1.141.900	190.000	3.046.700	13.1	23.3	2.47[b]	1.40	3.3	55¾-28¼	17.0
1986	4.835.900	589.500	3.993.900	2.5	1.070.000	221.900	2.646.500	12.2	22.3	2.07	1.06	2.9	44¼-30⅛	18.0
1985	4.444.000	531.400	3.557.300	2.3	925.800	222.000	2.287.100	12.0	23.2	1.93	0.905	3.1	34¼-24½	15.2
[illegible]														
1988	$4.069.700	$ 761.000	$4.852.800	1.7	$1.806.600	$372.100	$2.815.400	18.7%	27.0%	$2.66	$1.15	2.8%	$ 45¾-35½	15.3
1987	3.643.800	410.500[c]	4.859.200	1.8	1.642.500	344.100	$2.646.900	11.3	15.5	1.41[c]	1.00	2.4	53⅝-28⅞	29.2
1986	3.720.400	558.200	4.117.000	1.7	1.527.600	283.000	2.260.800	15.0	24.7	2.00	0.90	2.7	41¾-25¼	16.7
1985	3.270.600	517.600	3.859.400	1.7	1.374.000	207.100	2.293.400	15.8	22.6	1.84	0.80	3.6	27⅞-16⅛	11.9
[illegible]														
1988	$5.939.500	$1.206.800	$5.992.100	1.7	$2.070.700	$372.700	$2.720.400	20.3%	44.4%	$3.05	$1.28	2.4%	$ 59⅝-48	17.6
1987	5.061.300	906.400	5.533.200	1.3	1.948.000	253.700	1.969.900	17.9	46.0	2.23	0.82	1.4	$ 74¼-40⅝	25.8
1986	4.128.900	675.700	4.967.900	1.7	1.906.200	210.600	2.431.800	16.4	27.8	1.62	0.63	1.9	43⅛-22⅜	20.3
1985	3.547.500	539.900	4.805.100	1.9	1.882.800	237.600	2.536.900	15.2	21.3	1.26	0.53	2.8	23-15	15.0
[illegible]														
1988	$5.385.400	$ 791.300	$7.218.200	1.7	$1.655.100	$343.700	$3.881.700	14.7%	20.4%	$4.70	$2.00	3.7%	$ 60¼-47⅜	11.4
1987	4.919.800	690.200	6.684.700	2.0	1.505.900	258.300	3.644.500	14.0	18.9	4.08	1.80	3.1	77-40	14.3
1986	4.476.000	660.000	4.946.700	1.9	1.351.300	196.100	3.198.200	14.7	20.6	3.90	1.64	2.8	72⅞-46¼	15.3
1985	4.024.500	579.700	4.341.500	2.1	1.268.300	195.800	2.805.900	14.4	20.7	3.44	1.48	3.2	56¼-37⅝	13.6
[illegible]														
1988	$2.969.400	$ 389.800	$3.234.500	1.2	$1.181.000	$156.100	$1.485.900	13.1%	26.2%	$3.48	$1.40	2.7%	$ 59⅜-45¼	15.0
1987	2.699.300	320.700[d]	3.053.200	1.2	1.131.100	118.000	1.317.300	11.9	24.3	2.77[d]	1.025	2.4	55¼-31¼	15.6
1986	2.398.700	265.800	2.862.000	1.3	1.143.500	124.800	1.319.700	11.1	20.1	2.17	0.90	2.5	44-28	16.6
1985	1.927.100	192.600	2.683.800	1.4	991.800	140.300	1.389.600	10.0	13.9	1.88	0.84	3.3	33¼-17⅝	13.5
[illegible]														
1988	$4.799.000	$ 475.700[e]	$4.033.100	1.0	$1.626.700	$298.700	$ 563.000	10.0%	84.5%	$3.83[e]	$1.84	3.7%	$ 59⅞-40⅞	13.2
1987	4.328.800	570.100	4.005.600	1.2	1.480.200	223.600	1.144.000	13.2	49.8	4.50	1.62	2.9	72¾-39¾	12.5
1986	3.745.400	521.100	3.891.400	1.3	1.410.800	236.700	965.400	13.9	54.0	3.39	1.50	3.4	52⅝-36¾	13.2
1985	3.256.600	514.400	3.534.500	1.8	1.285.300	248.000	2.070.100	15.8	24.8	3.28	1.425	4.3	39¾-26⅛	10.1
[illegible]														
1988	$2.585.804	$ 425.456	$3.083.114	1.2	$ 938.491	$218.824	$1.400.613	16.5%	30.4%	$4.30	$1.60	2.5%	$ 70⅝-55½	14.7
1987	2.156.503	358.441	2.782.375	1.5	784.841	166.539	1.525.451	16.6	23.5	3.42	1.20	1.5	102⅞-55¼	23.1
1986	1.784.629	263.639[f]	2.408.831	1.8	645.630	95.077	1.358.096	14.8	19.4	2.45[f]	0.97	1.9	62-38⅛	20.4
1985	2.041.745	226.599	2.396.592	2.0	701.439	120.342	1.409.382	11.1	16.1	2.10	0.86	2.6	41¼-24⅞	15.7
[illegible]														
1988	$2.746.248	$ 353.418	$3.139.328	1.6	$1.239.598	$240.997	$1.820.952	12.9%	19.4%	$1.90	$0.80	2.6%	$ 35¼-26⅞	16.3
1987	2.521.024	305.039	3.043.131	1.9	1.114.391	211.976	1.673.512	12.1	18.2	1.63	0.63	1.6	53¾-23¼	23.6
1986	2.280.325	252.646	2.664.956	1.9	981.549	201.920	1.470.216	11.1	17.2	1.35	0.51	1.8	35½-20½	20.7
1985	2.008.486	203.193[g]	2.376.873	1.8	852.054	152.637	1.295.085	10.1	15.7	1.10[g]	0.45	2.6	23⅝-11⅛	15.8
[illegible]														
1988	$3.908.400	$ 340.300	$2.554.100	1.1	$1.053.000	$189.600	$ 849.900	8.7%	40.0%	$5.00	$2.16	3.1%	$ 79½-59⅞	13.9
1987	3.484.700	295.800	2.396.500	1.1	959.800	176.900	795.000	8.5	37.2	4.15	1.77	2.6	87½-48¼	16.4
1986	3.102.918	261.784[h]	2.479.054	1.4	819.291	137.996	870.453	8.4	30.1	3.54[h]	1.59	2.9	63⅛-45	15.3
1985	3.200.069	237.704[i]	2.286.187	1.2	868.931	138.774	819.279	7.4	29.0	3.05[i]	1.50	3.2	49⅜-33⅜	13.6

a Includes gain on sale of Brach confectionary business and Household Research subsidiary, before taxes, of $535 million. **b** Includes gain on sale of orthodontic and animal health businesses, before taxes, of $80.3 million. **c** From continuing operations; includes restructuring charges, before taxes, of $271.9 million but excludes net income and net gain on sale of discontinued cosmetics business of $233.2 million ($0.79 per share). **d** Excludes nonrecurring net charge of $4.3 million ($0.04 per share). **e** Excludes restructuring and other nonrecurring net charges of $389.3 million ($2.36 per share) and net gain on subsidiary sale of stock of $46.1 million ($0.37 per share). **f** From continuing operations; excludes net income from discontinued operations of $13.1 million ($0.12 per share), net gain on disposal of discontinued operations of $187.6 million ($1.75 per share), and extraordinary net charge for write-off of certain foreign assets of $68.0 million ($0.63 per share). **g** From continuing operations; excludes net loss from operations and sale of polymer chemical business of $238,000. **h** Excludes net nonrecurring credit from write-down and divestiture of assets and restructuring program of $47.7 million ($0.64 per share). **i** Excludes net nonrecurring charge for write-down and divestiture of assets and restructuring program of $553.3 million ($7.10 per share).

3 Employment in the Chemical Industry

Chemical employment growth continues

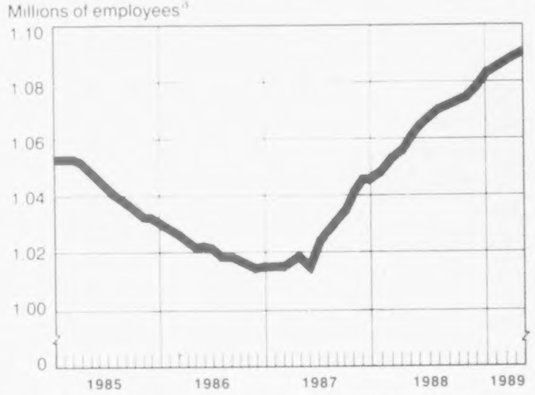
The number of workers employed in the U.S. chemical industry rose again in 1988, reaching an annual average of 1,063,000. Even so, the 3% increase from the year before did not bring the total up to the level it was in the early 1980s, when the industry had more than 1.1 million workers. Employment in most segments of the industry increased, rising most in the drugs and cleaners sectors, but it remained steady in the paints and agricultural chemicals sectors.

With business continuing strong for chemical firms, employment is rising further this year, topping 1,080,000 this past spring.

Hiring in major individual chemical firms reversed the downtrend of 1987 and 1986. Total employment among 22 firms edged up only 0.8%, however, and still is much lower than in 1985.

Total employment of scientists and engineers in the chemical industry climbed 2% after falling in 1987 for the first time since 1976. It is now more than 50% higher than in 1978.

Employment in the chemical industry has been on the uptrend in the past two years



a Seasonally adjusted employment in U.S. chemicals and allied products industry. April and May 1989 figures are preliminary. **Source:** Department of Labor

INDUSTRIAL EMPLOYMENT: Gains in major chemical sectors last year

	All employees[a] (thousands)				Production workers[a] (thousands)				Workweek[a,b] (hours)			
	1988	1987	1986	1978	1988	1987	1986	1978	1988	1987	1986	1978
All manufacturing	19,539	19,065	18,965	20,332	13,338	12,995	12,877	14,610	41.1	41.0	40.7	40.4
Chemicals and allied products	1,063	1,026	1,022	1,088	598	576	568	624	42.3	42.3	41.9	41.9
Industrial inorganic chemicals	133	131	135	164	67	67	69	93	43.0	42.4	42.0	42.1
Plastics materials and synthetics	170	166	168	214	112	110	113	145	43.4	43.1	42.1	42.4
Drugs	229	215	208	184	103	99	96	88	41.1	41.6	41.6	41.3
Soap, cleaners, and toilet goods	163	154	147	135	105	98	93	82	40.2	41.1	41.0	40.5
Paints and allied products	62	62	63	70	31	31	37	37	41.9	41.7	41.6	41.4
Industrial organic chemicals	156	151	154	164	90	85	81	85	44.2	44.1	43.4	42.5
Agricultural chemicals	52	52	54	70	34	32	33	44	43.4	42.9	42.2	42.6
Miscellaneous chemical products	98	96	94	88	57	55	53	50	42.0	41.5	41.3	41.6
Petroleum and coal products	167	165	169	209	108	108	106	137	44.4	44.0	43.8	43.6
Rubber and miscellaneous plastics products	873	823	790	749	679	639	615	587	41.6	41.6	41.3	40.8

a Domestic employment. b Workweek of production or nonsupervisory workers. **Source:** Department of Labor

EMPLOYMENT OF SCIENTISTS, ENGINEERS: Down for second year for industrial chemicals

Thousands[a]	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978
Total, all industry	725.8	703.8	676.5	626.2	586.5	541.9	509.8	487.8	450.6	423.9	404.4
Chemicals and allied products	74.9	73.0	75.8	71.1	69.8	67.3	61.6	54.7	51.4	50.0	48.3
Industrial chemicals	23.2[b]	24.4	24.9	23.5	25.6	26.6	25.9	21.6	20.9	21.4	21.3
Drugs and medicines	31.2	29.2	31.8	30.8	30.8[b]	28.2	25.6	23.3	21.6	20.8	19.5
Other chemicals	20.5	19.4	19.1	16.7	13.4	12.1	10.1	9.8	8.9	7.8	7.5
Petroleum refining	9.5	8.6	10.4	13.5	13.3	14.7	15.6	13.0	10.8	10.1	9.9
Rubber products	na	12.5	13.0	13.0	na	na	8.1	10.3	na	8.1	7.9

a Full-time equivalent number of R&D scientists and engineers in industry, as of January of each year. b Partly estimated. **na** = not available separately, but included in total. **Source:** National Science Foundation

3 Employment in the Chemical Industry

CHEMICAL EMPLOYMENT: Up slightly last year but still far below pre-1986 levels

Thousands	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978
Air Products	13.3	12.1	16.6	18.7	17.7	16.7	18.9	16.2	15.8	14.6	14.3
American Cyanamid	35.5	34.3	34.5	36.4	38.2	38.7	40.2	41.8	42.6	44.2	44.0
Betz Laboratories	3.1	2.0	2.6	2.5	2.5	2.3	2.2	2.2	2.1	2.0	1.8
Cabot Corp.	5.2	5.1	6.6	7.7	7.5	7.2	7.5	7.7	7.6	8.1	7.9
Chemed	5.6	4.8	4.8	4.3	4.3	4.1	3.5	3.6	3.6	3.3	3.1
Crompton & Knowles	1.6	1.3	1.3	2.3	2.3	2.4	2.3	2.5	2.8	3.0	3.2
Dow Chemical	55.5	53.1	51.3	53.2	49.8	54.5	56.6	63.8	56.8	55.9	53.5
Ethyl	10.4	10.0	10.5	10.5	11.0	13.0	14.0	14.5	15.0	16.0	16.5
H. B. Fuller	5.2	4.6	4.5	4.4	4.3	4.1	4.0	3.3	3.4	3.4	3.3
W. R. Grace	45.7	39.4	41.4	116.9	102.6	95.5	82.2	89.0	92.0	82.8	69.1
Hercules	22.7	23.2	25.1	25.4	26.3	24.2	24.5	25.9	26.1	27.4	27.1
International Flavors	4.2	4.1	3.8	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.5
International Minerals	6.9	12.9	13.9	8.7	9.0	8.4	8.4	10.6	10.6	10.3	9.9
Lubrizol	4.8	4.8	4.8	5.2	4.2	4.2	4.3	4.2	4.2	3.9	3.8
Monsanto	45.6	49.7	51.7	56.1	50.8	48.8	52.2	57.4	61.8	63.9	62.9
Nalco Chemical	5.4	5.1	4.9	5.1	4.8	4.6	4.6	4.7	4.3	4.1	4.1
Olin	16.4	14.1	13.2	14.9	17.8	18.2	17.5	20.3	21.0	21.7	22.7
PPG Industries	36.3	36.8	36.5	37.5	37.7	37.0	37.0	36.6	37.3	38.2	37.4
Pennwalt	5.0	9.0	9.6	9.9	9.8	9.8	9.5	10.7	12.8	13.3	14.0
Rohm & Haas	12.4	12.0	12.1	11.8	11.9	11.4	11.5	13.5	13.2	13.3	13.1
Stepan	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.9	0.8
Union Carbide	44.0	43.1	50.3	91.5	98.4	99.5	103.2	110.3	116.1	115.8	113.4
TOTAL EMPLOYEES	**385.8**	**382.6**	**400.9**	**527.6**	**515.5**	**509.1**	**508.6**	**543.3**	**553.4**	**549.7**	**529.5**
ANNUAL CHANGE	**0.8%**	**−4.6%**	**−24.0%**	**2.4%**	**1.2%**	**0.1%**	**−6.4%**	**−1.8%**	**0.7%**	**3.8%**	**1.6%**
SALES PER EMPLOYEE ($ thousands, current)	**$179.6**	**$159.9**	**$135.3**	**$114.4**	**$115.5**	**$110.0**	**$107.7**	**$109.3**	**$101.8**	**$ 92.6**	**$ 79.7**
SALES PER EMPLOYEE ($ thousands, constant 1982[a])	**$154.3**	**$150.3**	**$132.0**	**$110.3**	**$112.3**	**$109.8**	**$107.7**	**$111.0**	**$114.3**	**$121.6**	**$117.1**

Note: Data are not restated for acquisitions, divestitures, or similar developments. a Based on producer price index for chemicals and allied products.

WAGES: Trend heads steadily upward in the chemical industry

	Hourly earnings[a]				Weekly earnings[a]			
	1988	1987	1986	1978	1988	1987	1986	1978
All manufacturing	$10.17	$ 9.91	$ 9.73	$6.17	$417.99	$406.31	$396.01	$249.27
Chemicals and allied products	12.67	12.37	11.98	7.01	535.94	523.25	501.96	293.72
Industrial inorganic chemicals	13.87	13.56	13.11	7.62	596.41	574.94	550.62	320.80
Plastics materials and synthetics	13.01	12.59	12.13	6.87	564.63	542.63	510.67	291.29
Drugs	12.05	11.62	11.16	6.42	495.26	483.39	464.26	265.15
Soap, cleaners, and toilet goods	11.05	10.90	10.76	6.66	444.21	447.99	441.16	269.73
Paints and allied products	11.24	10.84	10.44	6.32	470.96	452.03	434.30	261.65
Industrial organic chemicals	15.06	14.90	14.39	8.23	665.65	657.09	624.53	349.78
Agricultural chemicals	12.29	11.91	11.44	6.69	533.39	510.94	482.77	284.99
Miscellaneous chemical products	11.53	11.36	11.07	6.54	484.26	471.44	457.19	272.06
Petroleum and coal products	15.05	14.59	14.19	8.60	668.22	641.96	621.52	374.96
Rubber and miscellaneous plastics products	9.11	8.91	8.73	5.50	378.98	370.66	360.55	224.40

a For production and nonsupervisory workers in domestic employment. **Source:** Department of Labor

CIRCLE 60 ON READER SERVICE CARD —

3 Employment in the Chemical Industry

With increases in production last year, productivity of workers in the U.S. chemical industry rose for the sixth straight year. And 1988's productivity increase soundly beat the increase that occurred in 1987. Meanwhile, unit labor costs for chemical production dropped once more after a very slight rise in the previous year. For both measures the chemical industry beat out performance for all manufacturing.

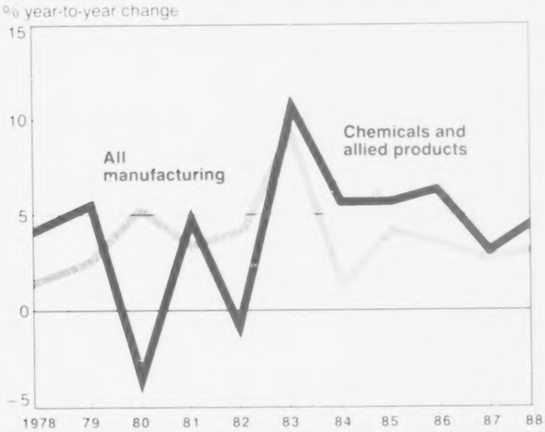
Based on government figures, C&EN calculates that productivity in the chemical industry increased 4.4% in 1988, compared with a 3.1% gain the year before. But last year's improvement was still below increases chalked up during the years immediately following the recession in the early 1980s. The productivity last year resulted from an 8.4% increase in production but only a 3.8% increase in hours worked in the chemical industry. Since 1982, production in the chemical industry has increased nearly 50%. But as a result of tightened efficiency and cutbacks in employment by the industry during the mid-1980s, workhours have remained practically unchanged. Consequently, productivity also has been lifted by more than 40%.

Meanwhile, unit labor costs, the measure of how much it costs in worker wages to produce a product, fell once again after a slight rise in 1987. The 1.9% decline last year is the fifth decrease in the past six years. In 1987, unit labor costs for chemicals and allied products were essentially flat, rising just 0.3% from the year before.

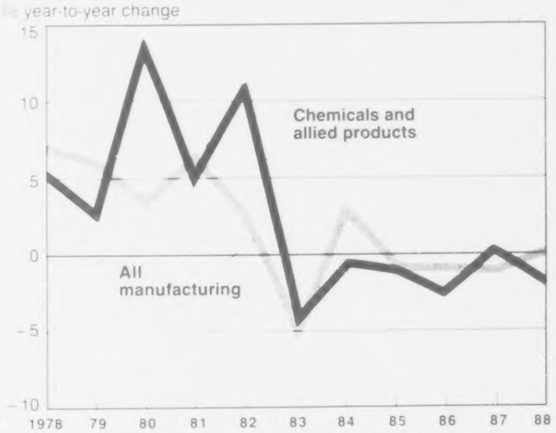
The chemical industry continued to outperform all manufacturing last year. Productivity for all manufacturing rose 3.0%, well below chemicals' 4.4%. And unit labor costs for all manufacturing were unchanged from the year before. In 1987, productivity for all manufacturing was up 2.7% and unit labor costs fell 1.0%.

One reason why productivity increased less for all manufacturing than in the chemical industry is that production in all manufacturing increased just 6% last year.

Productivity improves for chemicals . . .



. . . pushing unit labor costs down further



Note: Productivity is output per workhour, calculated by dividing indexes for production by indexes for workhours of production employees. Unit labor costs are labor costs per unit of output, calculated by dividing indexes for wages by indexes for output per workhour. **Sources**: Federal Reserve Board, Department of Labor, C&EN estimates

PRODUCTIVITY Strong growth in output spurs further improvement

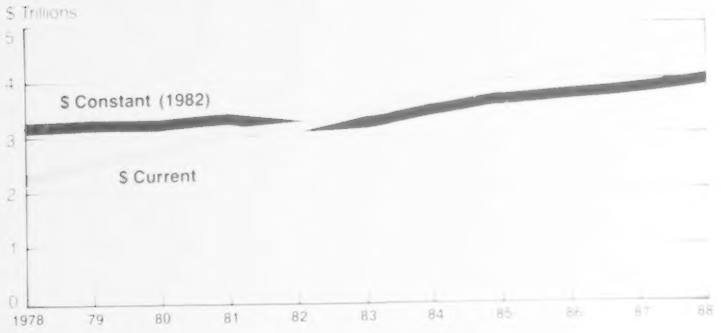
Indexes, 1977 = 100	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978
CHEMICALS AND ALLIED PRODUCTS											
Production	151.9	140.2	133.0	127.1	121.6	113.9	103.8	112.6	106.4	113.3	106.3
Workhours	98.3	94.7	92.6	94.1	95.0	93.9	95.2	101.7	101.0	103.1	102.2
Productivity	154.5	148.0	143.6	135.1	128.0	121.3	109.0	110.7	105.3	109.9	104.0
Hourly production wages	197.0	192.4	186.1	180.1	172.7	164.8	155.0	141.8	129.2	118.2	109.2
Unit labor costs	127.5	130.0	129.6	133.3	134.9	135.9	142.2	128.1	122.6	107.6	105.0
ALL MANUFACTURING											
Production	142.7	134.7	129.2	126.4	123.4	113.9	102.2	110.5	108.2	110.7	106.1
Workhours	96.1	93.4	92.0	93.1	94.8	88.2	87.0	97.9	98.9	106.4	104.5
Productivity	148.5	144.2	140.4	135.8	130.2	129.1	117.5	112.9	109.4	104.0	101.5
Hourly production wages	179.1	174.0	171.1	166.9	161.5	155.4	149.6	140.7	128.1	118.0	108.6
Unit labor costs	120.6	120.7	121.8	122.9	124.1	120.3	127.4	124.7	117.1	113.4	107.0

Sources: Federal Reserve Board, Department of Labor, C&EN estimates

Markets for the U.S. Chemical Industry

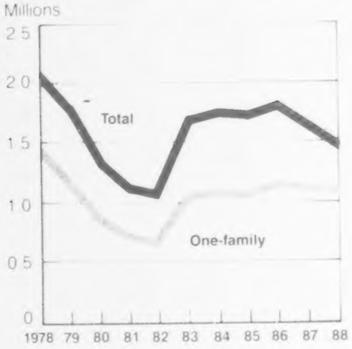
For the sixth year in a row, the willingness of U.S. consumers to keep their purse strings open has propelled the U.S. economy forward. Spending for personal consumption was up 7% in 1988—or nearly 3% if allowance is made for inflation. That's a rate of growth that has changed little in the past two or three years and is still strong enough to keep the overall economy in an expansionary mode. And because the chemical industry's diverse array of products more often than not eventually find their way directly or indirectly into consumer products, chemical producers have benefited greatly from the uptrend.

Gross national product



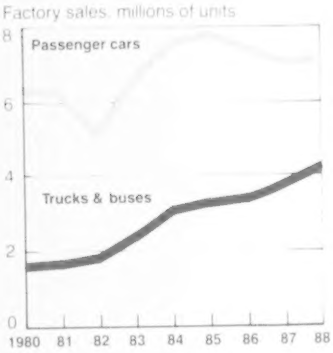
Source [illegible]

Housing starts



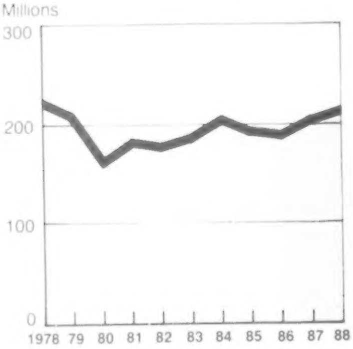
Source: Bureau of the Census

Motor vehicles



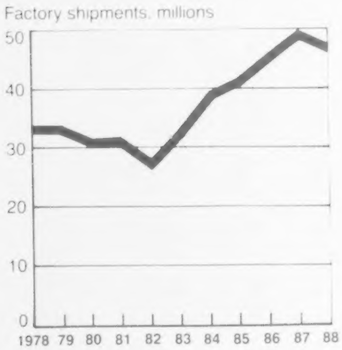
Source: Motor Vehicle Manufacturers Association

Tires and tubes



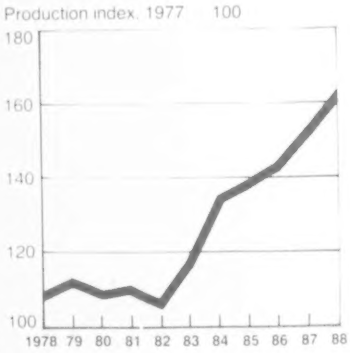
Source: Rubber Manufacturers Association

Major home electrical appliances



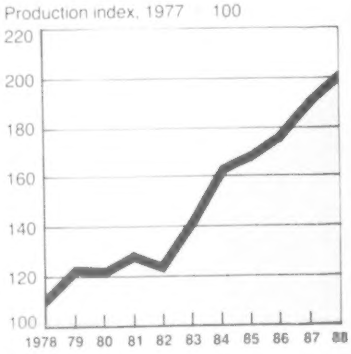
Source: Association for Home Appliance Manufacturers

Furniture and fixtures



Source: Federal Reserve Board

Miscellaneous plastics products

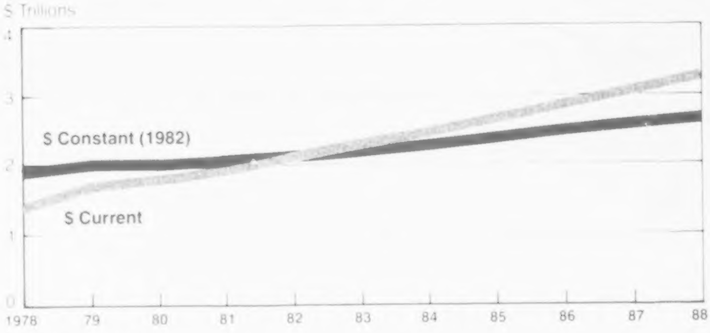


Source: Federal Reserve Board

Not all of the industry's markets have been equally firm recently, to be sure. New housing, one of the most important, has been weakening since 1986, and new housing starts are expected to dwindle a bit further again this year. Although auto assemblies are up nearly 5% so far in 1989, slower sales may well lead to lower car output in the U.S. for the year as a whole. Other markets, too, have started to show some hints of slackening.

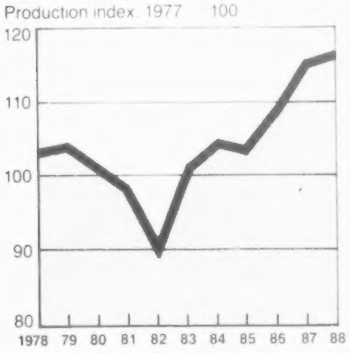
For 1989, therefore, markets for chemicals overall may noticeably soften, in line with the U.S. economy in general. Nevertheless, most industry observers remain convinced that, as long as consumers remain in a spending mood, this year will see new records set in demand for chemical products as a group.

Personal consumption expenditures



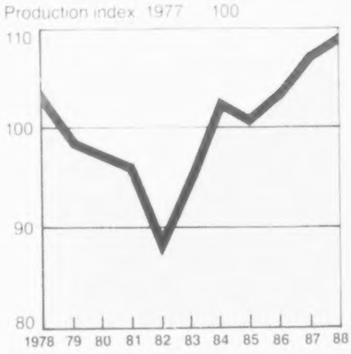
Source: [illegible]

Textile mill products



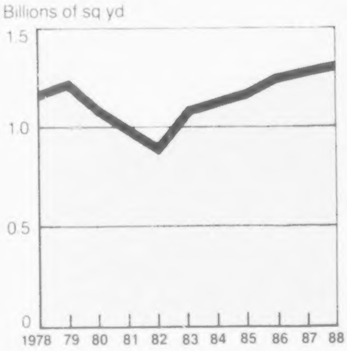
Source: Federal Reserve Board

Apparel



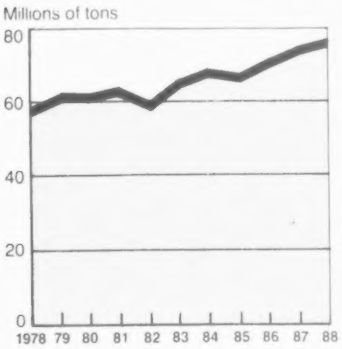
Source: Federal Reserve Board

Floor coverings



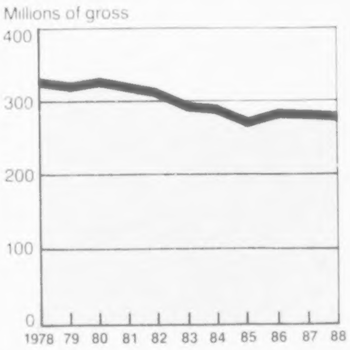
Source: Bureau of the Census

Paper and paperboard



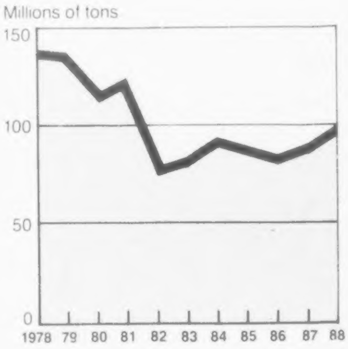
Source: American Paper Institute

Glass containers



Source: Bureau of the Census

Steel



Source: American Iron & Steel Institute

U.S. chemical trade surplus sets a new high

Growth in economic activity was robust throughout the industrialized world last year. One result was that world trade in chemicals, measured in U.S. dollars, rose a healthy 14% to almost a quarter of a trillion dollars.

And aided by the continued depressed level of the U.S. dollar vis-à-vis currencies of most of the rest of the industrialized countries, U.S. chemical makers managed to garner a slightly larger share of the total global market after having experienced a three-year decline in their market share. U.S. exports, all in all, swelled 22% to a record $32 billion, the biggest one-year advance since 1979. Sales were particularly strong to China and other Asian developing countries. Best showing among major product areas was tallied by plastics, with foreign customers upping their purchases by about a third.

But trade is a two-way street. And with the U.S. economy still buoyant, U.S. capacity strained for many chemical products, and several foreign competitors expanding their output, imports of chemicals increased at about the same clip, also hitting a new peak of just under $20 billion. Latin American producers boosted their sales to the U.S. about 40%.

Even so, the U.S. balance of trade in chemicals expanded for the third year in a row to $12.4 million, edging just above its previous all-time high set in 1980. Although the U.S. dollar has strengthened a bit this year, it is still markedly weaker relative to other major world currencies than it was before 1987. And the largest markets still seem healthy. U.S. chemical companies, therefore, are looking for further gains in their overseas sales and the nation's chemical trade surplus is likely to widen again this year.

U.S. TOTAL TRADE BALANCE

Deficit narrows moderately

$ Billions	1988	1987	1986	1978
Total exports	$ 322.2	$ 254.1	$ 227.2	$ 143.8
Total imports	440.9	406.2	365.4	172.0
Trade balance	−118.7	−152.1	−138.2	−28.2

Source: Department of Commerce

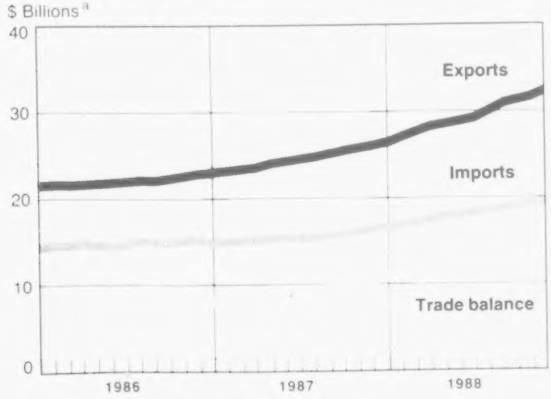
U.S. CHEMICAL TRADE BALANCE

Surplus continues to widen

$ Millions	1988	1987	1986	1978
Chemical exports	$32,300	$26,381	$22,766	$12,618
Chemical imports	19,876	16,213	15,001	6,427
Chemical trade balance	12,424	10,168	7,765	6,191

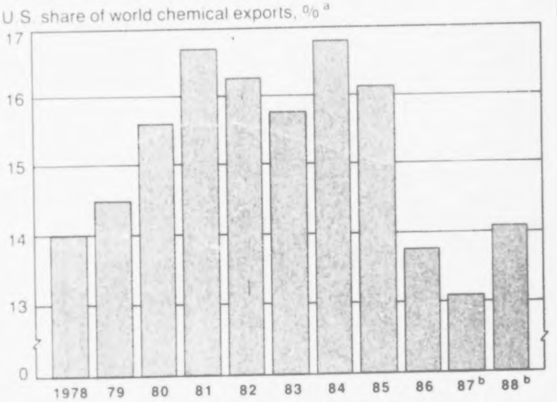
Source: Department of Commerce

Strong growth for U.S. chemical exports . . .



a Running 12-month totals. **Source:** Department of Commerce

. . . brings upturn in share of world market



a U.S. chemical exports as a percentage of total world chemical exports less chemical imports. b C&EN estimates

U.S. TRADE: **Growth continues worldwide**

$ Millions	1988	1987	1986	1978
U.S. CHEMICAL EXPORTS				
Canada	$ 3,800	$ 3,277	$ 2,668	$ 1,739
Latin America	5,145	4,407	4,025	2,679
Western Europe	9,276	7,987	7,032	4,275
Eastern Europe	341	344	385	62
Communist Asia	1,388	808	441	61
Japan	4,002	3,422	3,081	1,104
Middle East	549	423	345	367
Rest of Asia	5,781	4,121	3,377	1,324
Australasia	1,080	834	689	417
Africa	600	500	447	349
Other	338	258	276	241
TOTAL	**$32,300**	**$26,381**	**$22,766**	**$12,618**
U.S. CHEMICAL IMPORTS				
Canada	$ 3,782	$ 3,052	$ 2,752	$ 1,805
Latin America	1,324	942	942	312
Western Europe	10,212	8,220	7,357	3,227
Eastern Europe	219	165	327	78
Communist Asia	234	200	179	34
Japan	2,187	2,150	1,792	563
Middle East	298	238	238	41
Rest of Asia	824	698	623	124
Australasia	322	235	221	115
Africa	103	74	326	46
Other	371	239	244	82
TOTAL	**$19,876**	**$16,213**	**$15,001**	**$ 6,427**

Source: Department of Commerce

WORLD TRADE: **Strong uptrend is maintained**

$ Millions	1988	1987	1986	1978
CHEMICAL EXPORTS				
World	$249,000[a]	$218,000[a]	$180,500[a]	$95,927
U.S.	32,300	26,381	22,766	12,618
Canada	6,266	4,639	3,968	2,111
EC, 12 countries	135,000[a]	119,600	97,961	55,205
Belgium-Luxembourg	13,050[a]	10,444	8,597	5,701
France	23,449	20,439	16,763	8,835
Italy	9,767	8,745	7,060	3,710
Netherlands	17,850[a]	16,740	13,786	7,425
U.K.	17,012	17,285	14,205	8,064
West Germany	43,819	38,172	31,202	18,835
Switzerland	11,800	9,976	8,124	4,804
Japan	13,964	11,662	9,484	5,102
CHEMICAL IMPORTS				
U.S.	$ 19,876	$16,213	$15,001	$ 6,427
Canada	5,825	4,708	4,199	2,556
EC, 12 countries	112,600[a]	95,898	78,167	40,095
Belgium-Luxembourg	11,400[a]	8,698	7,119	4,627
France	19,545	16,892	13,708	7,280
Italy	16,049	13,689	11,001	4,725
Netherlands	11,650[a]	9,653	7,889	4,175
U.K.	15,290	13,680	10,772	5,293
West Germany	24,299	21,454	17,686	8,785
Switzerland	7,600	5,721	4,796	2,421
Japan	14,830	11,845	9,733	3,763

[a] C&EN estimates. **Sources:** United Nations, Organization for Economic Cooperation & Development, European Community, individual government agencies

U.S. TRADE, BY PRODUCTS: **Organic chemicals and plastics account for about half**

	Chemical exports				Chemical imports			
$ Millions	1988	1987	1986	1978	1988	1987	1986	1978
Organic chemicals	$ 9,381	$ 7,550	$ 6,293	$ 3,369	$ 6,953	$ 5,408	$ 4,704	$1734
Plastics and resins	7,277	5,492	4,301	2,088	2,433	1,987	1,837	518
Medicinals and pharmaceuticals	3,941	3,182	3,090	1,404	1,859	1,456	1,240	449
Inorganic chemicals	2,702	2,112	1,771	1,207	2,498	2,030	1,894	915
Fertilizers, manufactured	2,498	2,259	1,935	1,091	1,021	795	865	869
Pesticides and disinfectants	910	732	664	445	577	398	580	159
Radioactive materials	868	1,017	1,302	717	1,098	1,012	1,382	912
Flavors, perfumes, cosmetics, and toiletries	709	579	488	356	932	796	679	230
Pigments, paints, and varnishes	449	411	333	241	395	427	348	63
Cleaning and polishing materials	395	357	302	250	260	205	214	62
Dyeing, tanning, and coloring materials	258	217	174	145	610	621	487	171
Explosives and pyrotechnics	91	91	81	65	118	110	111	43
Miscellaneous	2,821	2,382	2,032	1,240	1,122	968	660	303
TOTAL	**$32,300**	**$26,381**	**$22,766**	**$12,618**	**$19,876**	**$16,213**	**$15,001**	**$6427**

Source: Department of Commerce

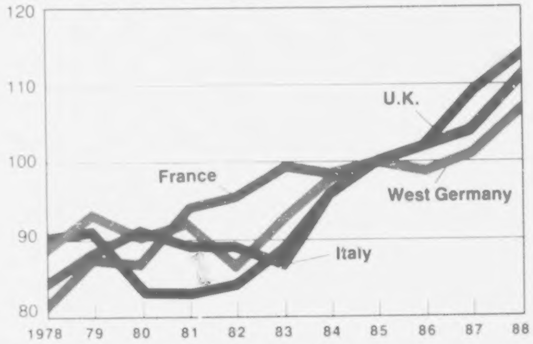
6 Foreign Chemical Industries — **Western Europe**

West Germany's three largest chemical companies—Bayer, BASF, and Hoechst—again were the leaders in chemical sales in Western Europe last year, although not quite in the same order as in previous years. And the U.K.'s ICI followed as a close fourth behind them. A significant gap remained between these four and the next tier, led by Ciba-Geigy of Switzerland and France's Rhône-Poulenc.

For chemical companies large or small, however, 1988 generally was a year of increased output and expansion, coupled with improved profit margins. Although production of a number of products declined in Italy and West Germany, solid gains in chemical output were widespread, particularly for such big-volume polymers as polyethylene, polypropylene, and polyvinyl chloride. Fiber production, for the most part, increased or at least held steady, an improvement from several years of losses.

Chemical output up sharply in recent years

Production index, 1985 = 100



Source: European Chemical Industry Federation (CEFIC)

CHEMICAL INDUSTRY TRENDS: **1988 was upbeat year for sales, production, and prices**

$ Billions (U.S.)	1988	1987	1986	1985	1984
WEST GERMANY					
Sales	$ 85.7	$ 78.0	$ 64.5	$ 50.5	$ 49.5
Exports	45.4	40.2	33.2	26.1	25.1
Imports	25.6	22.6	18.8	15.0	14.0
Capital spending	6.0	5.3	3.5	2.4	2.2
Production index[a]	106.5	101.1	99.1	100.0	97.9
Price index[a]	92.4	91.1	94.2	100.0	97.1
Employees (thousands)	575	572	567	557	550
FRANCE[c]					
Sales	$ 53.3	$ 47.4	$ 40.7	$ 31.8	$ 30.9
Exports	21.9	19.0	15.7	12.8	12.2
Imports	18.2	15.4	12.5	10.0	9.2
Capital spending	2.9	2.5	1.9	1.3	1.1
Production index[a]	111.2	104.1	101.0	100.0	98.3
Price index[a]	100.2	96.3	97.5	100.0	102.2
Employees (thousands)	266	268	268	272	279
U.K.[b]					
Sales	$ 44.5	$ 36.9	$ 30.6	$ 26.3	$ 25.2
Exports	20.1	17.3	14.3	12.1	11.0
Imports	16.6	13.7	11.0	9.0	8.8
Capital spending	3.0	2.3	1.9	1.6	1.4
Production index[a]	114.3	109.0	101.1	100.0	95.4
Price index[a]	111.6	105.8	101.4	100.0	95.1
Employees (thousands)	346	336	336	336	329
ITALY					
Sales	$ 42.8	$ 37.5	$ 30.7	$ 24.5	$ 23.6
Exports	10.9	9.3	7.8	6.6	6.2
Imports	17.1	14.7	12.0	9.3	8.6
Capital spending	2.1	1.8	1.3	0.9	0.9
Production index[a]	110.5	103.6	101.4	100.0	96.3
Price index[a]	107.5	100.4	97.3	100.0	92.8
Employees (thousands)	223	225	230	233	241
SPAIN[b]					
Sales	$ 30.4	$ 25.8	$ 20.7	$ 16.1	$ 15.2
Exports	5.0	4.2	3.1	2.9	2.7
Imports	7.5	6.3	4.7	3.1	3.0
Capital spending	0.6	0.5	0.4	0.3	0.2
Production index[a]	122.5	112.4	105.0	100.0	97.4
Price index[a]	104.6	102.5	101.0	100.0	93.0
Employees (thousands)	239	239	239	240	241
BELGIUM[b, c]					
Sales	$ 22.7	$ 19.8	$ 17.2	$ 14.1	$ 13.6
Exports[d]	16.4	14.7	12.2	9.6	9.1
Imports[d]	13.5	10.7	8.6	6.9	6.6
Capital spending	1.5	1.0	0.7	0.4	0.4
Production index[a]	120.0	110.6	102.6	100.0	96.8
Price index[a]	97.0	94.0	97.7	100.0	96.5
Employees (thousands)	92	91	91	90	89
NETHERLANDS					
Sales	$ 22.3	$ 19.5	$ 16.0	$ 13.9	$ 13.6
Exports	21.8	19.0	15.7	12.9	12.5
Imports	12.6	11.5	9.5	8.0	7.2
Capital spending	1.8	1.5	1.2	0.8	0.8
Production index[a]	108.5	104.0	100.0	100.0	91.7
Price index[a]	88.5	87.0	85.4	100.0	94.3
Employees (thousands)	92	91	91	89	89
SWITZERLAND[b]					
Sales	$ 12.8	$ 11.5	$ 9.3	$ 6.7	$ 6.5
Exports	10.9	9.8	7.9	5.7	5.4
Imports	6.4	5.6	4.7	3.6	3.4
Production index[a]	120.0	105.3	102.1	100.0	94.1
Price index[a]	91.9	90.8	97.3	100.0	95.9
Employees (thousands)	70	69	68	66	65
SWEDEN					
Sales	$ 7.6	$ 6.3	$ 5.0	$ 4.1	$ 4.1
Exports	3.6	3.0	2.5	1.9	1.8
Imports	4.6	3.9	3.2	2.7	2.5
Capital spending	0.5	0.5	0.4	0.3	0.3
Production index[a]	na	106.3	99.3	100.0	100.5
Price index[a]	na	103.2	101.6	100.0	94.5
Employees (thousands)	46	45	42	43	44
FINLAND					
Sales	$ 3.9	$ 3.6	$ 3.1	$ 2.4	$ 2.4
Exports	0.6	0.6	1.2	1.0	1.0
Imports	1.0	1.1	2.1	1.6	1.5
Capital spending	1.1	0.5	0.4	0.3	0.3
Production index[a]	98.5	92.1	102.1	100.0	96.0
Price index[a]	99.7	94.5	96.3	100.0	na
Employees (thousands)	24	24	24	25	25
NORWAY					
Sales	$ 3.2	$ 2.9	$ 2.3	$ 2.0	$ 2.1
Exports	1.9	1.6	1.3	1.2	1.2
Imports	1.9	1.6	1.4	1.1	1.0
Capital spending	0.2	0.2	0.2	0.1	0.1
Production index[a]	103.0	103.0	100.0	100.0	96.0
Price index[a]	na	106.0	101.5	100.0	100.9
Employees (thousands)	15	15	15	15	16

a 1985 = 100. **b** Excludes fibers. **c** Includes rubber and plastics processing. **d** Includes Luxembourg for exports and imports. **na** = not available. **Sources:** National agencies and European Chemical Industry Federation (CEFIC)

6 Foreign Chemical Industries — **Western Europe**

MAN-MADE FIBERS: Generally little or no growth in output for major producing countries

Millions of lb	1988		1987		1986		1985		1984		Change, 1987–88	
	Non-cellulosics	Cellulosics	Non-cellulosics	Cellulosics	Non-cellulosics	Cellulosics	Non-cellulosics	Cellulosics	Non-cellulosics	Cellulosics	Non-cellulosics	Cellulosics
West Germany	1817	376	1806	356	1738	354	1764	372	1674	359	1%	6%
Italy	1452	55	1441	64	1430	66	1409	67	1329	68	1	14
Turkey	620	20	572	18	504	18	409	18	356	11	8	11
Spain	590	81	591	78	601	80	633	80	599	73	0	4
U.K.	515[a]	238[b]	513[a]	208[b]	524[a]	207[b]	557[a]	247[b]	561[a]	372[b]	0	14
France	392	33	382	50	392	45	427	44	456	61	3	−34
Benelux countries	385	119	399	109	379	108	365	95	318	94	−4	9
Switzerland	242	0	227	0	216	0	226	0	218	0	7	—
Ireland	176	0	172	0	162	0	140	0	136	0	2	—
Portugal	128	2	139	2	136	2	134	1	119	1	−8	0
Austria	70	290	68	264	61	271	63	265	59	267	3	10
Finland	7	132	4	118	3	121	3	134	3	143	75	12

a Includes cellulose acetate filament. **b** Excludes cellulose acetate filament. **Source:** Comite International de la Rayonne et des Fibres Synthetiques

PRODUCTION: Biggest increases last year were in petrochemicals and plastics

Millions of lb	1988	1987	1986	1985	Change 1987–88
FRANCE					
Sulfuric acid	8846	8618	8826	9433	3%
Hydrochloric acid	1507	1427	1381	1446	6
Chlorine	3121	2971	3151	3060	6
Sodium hydroxide	3258	3123	3304	3196	4
Ammonia	4031	4466	4455	4422	−10
Benzene	1544	1439	1332	1399	7
Toluene	104	72	83	89	44
Xylenes	493	284	250	277	74
Ethylene	5361	5319	4980	4749	1
Propylene	3298	3073	2283	2730	7
Butadiene	737	677	641	634	9
Formaldehyde	193	180	176	203	7
Polyethylene	2620	2523	2471	2266	4
Polypropylene	1278	1159	1034	933	10
Polystyrene	1177	1166	1089	1074	1
Polyvinyl chloride	2237	2039	1960	1804	10
Synthetic rubber	1251	1184	1193	1199	6
Phosphate fertilizers[a]	700	1209	1267	1340	−42
ITALY					
Sulfuric acid	9714[b]	9589	9170	9588	1%
Nitric acid	2580[b]	2422	2402	2599	7
Phosphoric acid	813[b]	842	830	886	−3
Chlorine	2351[b]	2294	2106	2031	2
Sodium hydroxide	2609[b]	2676	2294	2268	−3
Sodium perborate	235[b]	245	212	218	−4
Ammonia	3793[b]	3839	4155	3250	−1
Benzene	1369[b]	1311	1107	1075	4
Toluene	503[b]	402	512	766	25
Xylenes	965[b]	1067	893	952	−10
Formaldehyde	279[b]	297	297	301	−6
Acetic acid	145[b]	140	116	129	4
Carbon black	436[b]	420	418	403	4
Polyethylene	1840[b]	1691	1504	1408	9
Polystyrene	639[b]	664	785	707	−4
Polyvinyl chloride	1718[b]	1380	1408	135	24
Nitrogen fertilizers[c]	7166[b]	6999	6948	7217	2

Millions of lb	1988	1987	1986	1985	Change 1987–88
U.K.					
Sulfuric acid	4967	4797	5125	5621	4%
Hydrochloric acid[d]	388	384	346	337	1
Chlorine	na	2256	2143	2269	—
Benzene	2072	2005	1876	1863	3
Ethylene	4464	3955	3828	3182	13
Propylene	2985	1929	1901	2141	55
Butadiene	527	509	424	655	4
Titanium dioxide	586	562	506	482	4
Acetone	280	259	271	323	8
Formaldehyde	246	250	227	272	−2
Polyethylene	1015	876	940	1144	16
Polypropylene	692	611	652	592	13
Polyvinyl chloride	353	390	400	391	−9
Synthetic rubber	688	565	636	593	22
WEST GERMANY					
Sulfuric acid	7186	7260	7344	7571	−1%
Hydrochloric acid	2160	2179	2048	2079	−1
Nitric acid	5098	5818	6210	6361	−12
Chlorine	7701	7595	7538	7686	1
Sodium hydroxide	7602	7523	7485	7581	1
Sodium carbonate	3089	3195	3173	3096	−3
Sodium sulfate	385	361	359	306	7
Carbon black	836	796	844	852	−2
Ammonia	4816	5098	4146	5036	−6
Benzene	3536	3316	3373	2723[e]	7
Toluene	1013	884	1052	860	15
Xylenes	1296	1102	1190	1089	18
Aniline	386	309	408	369	25
Ethylene	6889	6118	5868	6661	13
Propylene	3396	3467	3093	3665	−2
Butadiene	1677	1543	1505	1851	9
Ethylene oxide	1381	1223	1098	1073	13
Ethylene glycol	521	536	500	504	−3
Propylene oxide	1209	1181	1174	1179	2
Propylene glycol	427	379	395	371	13
***n*-Butanol**	685	689	689	604	−1
Acetaldehyde	789	727	686	726	9
Acetic acid	754	704	653	655	7
Ethanol	228	240	217	170	−5
Formaldehyde	1505	1341	1265	1253	12
Phthalic anhydride	612	522	433	378	17
Polyethylene	3235	2980	2785	2725	9
Polyvinyl chloride	3105	2904	2732	2658	7
Synthetic rubber	1101	1035	1026	1007	6
Nitrogen fertilizers[c,f]	na	1674	1684	1826	—

a As P_2O_5. **b** C&EN estimates. **c** As N. **d** Manufacturers' sales. **e** From petroleum refining only. **f** Excludes calcium cyanamid fertilizers. **na** = not available. **Sources:** Government agencies for each country

COMPANY RESULTS: With profitability up throughout Europe, plant and R&D outlays rise

$ Millions	Net sales	Net income	Profit margin	Capital spending	R&D spending	Employees (thousands)
BASF (West Germany)						
1988	$24,925.0	$ 813.8	3.3%	$1985.8	$1016.5	134.8
1987	22,354.4	586.1	2.6	1532.2	896.1	133.8
1986	18,650.2	419.4	2.2	1224.4	676.5	131.5
1985	15,094.2	339.5	2.2	950.3	488.1	130.2
Hoechst (West Germany)						
1988	$23,275.0	$1144.9	4.9%	$1579.5	$1372.7	164.5
1987	20,531.1	848.9	4.1	1330.0	1231.7	167.8
1986	17,518.0	644.7	3.7	1234.6	985.3	181.2
1985	14,531.3	499.3	3.4	804.4	708.5	180.6
Bayer (West Germany)						
1988	$22,993.2	$1090.3	4.7%	$1786.9	$1397.7	165.7
1987	20,635.0	857.8	4.2	1425.0	1301.7	164.4
1986	18,778.3	687.1	3.7	1093.5	955.8	173.0
1985	15,621.1	488.4	3.1	700.0	725.9	176.1
ICI (U.K.)						
1988	$20,816.7	$1567.6[a]	7.5%	$1443.1	$1005.3	130.4
1987	18,234.4	1245.9	6.8	1160.7	755.7	127.8
1986	14,862.2	879.8[b]	5.9	942.8	573.3	121.8
1985	13,892.5	715.0[c]	5.1	821.2	452.1	118.6
Ciba-Geigy (Switzerland)						
1988	$12,087.0	$ 907.5	7.5%	$1106.8	$1230.8	88.8
1987	10,579.9	738.3	7.0	918.1	1122.8	86.1
1986	8,863.9	645.0	7.3	684.4	903.9	82.2
1985	7,406.9	598.4	8.1	493.1	680.5	81.0
Rhone-Poulenc (France)						
1988	$10,962.1	$ 580.0	5.3%	$ 990.1	$ 641.4	79.7
1987	9,344.3	392.7	4.2	830.4	585.4	83.0
1986	7,603.8	289.8	3.8	732.5	426.3	78.0
1985	6,240.5	257.1	4.1	460.5	317.6	78.0
Montedison (Italy)						
1988	$10,846.4	$ 483.9[d]	4.4%	$ 823.3	$ 389.6	47.1
1987	10,641.2	436.7	4.1	786.3	290.9	47.9
1986	8,607.6	(46.1)[e,f]	—	570.8	207.9	66.6
1985	7,402.8	126.3[g]	1.7	342.6	157.2	69.7
Norsk Hydro (Norway)						
1988	$ 9,206.7	$ 526.7[h]	5.7%	$1355.2	$ 113.5	39.5
1987	8,086.5	311.0[h]	3.8	1451.0	97.2	39.1
1986	7,341.0	(41.4)[e,h]	—	1562.7	81.2	43.1
1985	5,512.8	263.6[h]	4.8	825.0	58.1	26.4
Akzo (Netherlands)						
1988	$ 8,374.2	$ 446.0	5.3%	$ 641.4	$ 409.0	71.1
1987	7,652.7	354.6[i]	4.6	539.4	362.1	67.4
1986	6,373.5	366.5[j]	5.7	451.4	304.5	68.4
1985	5,424.7	275.1[k]	5.1	303.6	218.4	65.0
Degussa (West Germany)						
1988	$ 7,730.1	$ 83.0	1.1%	$ 255.3	$ 213.1	32.4
1987	6,510.6	67.2	1.0	230.9	150.0	30.8
1986	5,010.1	53.0	1.1	212.0	108.3	25.0
1985	3,984.4	38.1	1.0	138.4	64.6	23.9

$ Millions	Net sales	Net income	Profit margin	Capital spending	R&D spending	Employees (thousands)
[illegible]						
1988	$ 6,986.3	$521.2	7.5%	$573.3	$624.7	48.0
1987	6,026.2	420.8	7.0	421.5	540.3	44.0
1986	4,645.0	300.6	6.5	306.1	414.4	42.6
1985	3,436.2	215.0	6.3	169.9	294.7	40.2
Solvay (Belgium)						
1988	$ 6,893.3	$410.9[l]	6.0%	$644.5	$293.4	44.3
1987	5,989.8	325.9[m]	5.4	498.3	247.1	45.0
1986	4,842.5	222.3[n]	4.6	517.1	192.6	44.8
1985	3,796.6	187.6[o]	4.9	271.1	131.8	44.5
Hoffmann-La Roche (Switzerland)						
1988	$ 5,952.3	$439.4	7.4%	$446.6	$828.9	49.7
1987	5,171.1	323.5	6.3	348.8	715.8	47.5
1986	4,345.7	231.1	5.3	293.7	623.7	46.5
1985	3,634.3	183.6	5.1	220.2	486.3	46.5
DSM (Netherlands)						
1988	$ 5,111.6	$399.5[p]	7.8%	$667.7	$181.8	28.6
1987	4,422.6	260.6[q]	5.9	431.0	140.4	27.9
1986	3,670.6	198.0[r]	5.4	329.0	91.8	27.3
1985[s]	7,128.6	142.8	2.0	294.3	57.2	26.1
Courtaulds (U.K.)						
1989[t]	$ 4,643.4	$248.9[u]	5.4%	$462.6	na	57.0
1988[t]	3,969.2	261.0[v]	6.6	320.3	na	68.5
1987[t]	3,708.0	213.0[w]	5.7	221.0	na	65.4
1986[t]	3,186.1	147.3	4.6	152.5	na	67.7
BOC International (U.K.)						
1988	$ 3,771.4	$365.1[x]	9.7%	$523.5	$ 83.3	38.8
1987	3,211.6	273.4[y]	8.5	362.5	61.5	35.5
1986	2,851.3	10.7[z]	0.4	347.4	55.7	37.7
1985	2,462.3	179.1[aa]	5.8	312.8	46.2	36.9
Nobel Industries (Sweden)						
1988	$ 3,488.1	$152.3	4.4%	$176.3	na	22.1
1987	2,195.6	98.1[bb]	4.5	162.9	na	18.1
1986	1,615.5	64.6[cc]	3.3	108.3	na	16.3
1985	1,266.2	11.5	0.9	71.7	na	15.9
Kemira (Finland)						
1988	$ 2,207.7	$117.4	5.3%	$345.7	na	14.9
1987	1,942.7	64.4	3.3	644.8	na	13.8
1986	1,322.9	56.6	4.3	231.2	na	11.6
1985	1,102.6	53.0	4.8	257.6	na	12.0
UCB (Belgium)						
1988	$ 949.0	$ 35.6[dd]	3.8%	$ 84.9	$ 45.1	na
1987	874.9	39.3[ee]	4.5	72.1	38.2	7.4
1986	659.4	31.5[ff]	4.8	40.2	28.7	6.5
1985	524.3	17.0[gg]	3.2	22.9	19.5	6.4
Laporte Industries (U.K.)						
1988	$ 918.7	$ 94.7	10.3%	$ 39.7	na	4.6
1987	758.4	80.5[hh]	9.8	27.9	na	4.2
1986	618.2	60.4[ii]	9.8	33.0	na	4.1
1985	481.0	46.2[jj]	9.6	33.0	na	3.6

a Excludes nonrecurring loss of $78.3 million. **b** Excludes nonrecurring loss of $63.0 million. **c** Excludes nonrecurring loss of $51.8 million. **d** Excludes nonrecurring minority interests' loss of $154.4 million. **e** Net loss. **f** Excludes nonrecurring gain of $17.6 million. **g** Excludes nonrecurring minority interests' loss of $68.1 million. **h** Restated to reflect full acquisition of Hydro Aluminum. **i** Excludes nonrecurring gain of $134.6 million. **j** Excludes nonrecurring gain of $9.5 million. **k** Excludes nonrecurring gain of $0.8 million and minority interests' loss of $22.0 million. **l** Excludes nonrecurring loss of $136.5 million. **m** Excludes nonrecurring loss of $90.5 million. **n** Excludes nonrecurring loss of $83.3 million. **o** Excludes nonrecurring loss of $50.5 million. **p** Excludes nonrecurring loss of $87.9 million. **q** Excludes nonrecurring loss of $40.4 million. **r** Excludes nonrecurring loss of $22.4 million. **s** Includes wholly owned DSM-Aardgas. **t** Fiscal year ends March 31. **u** Excludes nonrecurring gain of $207.7 million. **v** Excludes nonrecurring loss of $25.9 million. **w** Excludes nonrecurring loss of $13.9 million. **x** Excludes nonrecurring loss of $42.2 million. **y** Excludes nonrecurring loss of $8.2 million. **z** Excludes nonrecurring loss of $5.0 million and pretax write-off of $187.7 million. **aa** Excludes nonrecurring loss of $4.9 million. **bb** Excludes nonrecurring gain of $17.8 million. **cc** Excludes nonrecurring loss of $13.2 million. **dd** Excludes nonrecurring gain of $2.7 million. **ee** Excludes nonrecurring loss of $3.2 million. **ff** Excludes nonrecurring loss of $2.3 million. **gg** Excludes nonrecurring loss of $6.2 million. **hh** Excludes nonrecurring loss of $1.8 million. **ii** Excludes nonrecurring gain of $7.8 million. **jj** Excludes nonrecurring gain of $4.1 million. **na** = not available.

NOTE ON CURRENCY CONVERSION

For monetary statistics in this section, European currencies were converted to U.S. dollars by the following conversion rates:

	$1.00 (U.S.) is equivalent to:									
	Belgium	France	Italy	Netherlands	Norway	Spain	Sweden	Switzerland	U.K.	West Germany
1988	36.77 francs	5.96 francs	1302 lire	1.98 guilders	6.52 crowns	116.49 pesetas	6.13 crowns	1.46 francs	0.562 pound	1.76 marks
1987	37.33 francs	6.01 francs	1296 lire	2.03 guilders	6.74 crowns	123.48 pesetas	6.34 crowns	1.49 francs	0.610 pound	1.80 marks
1986	44.67 francs	6.93 francs	1491 lire	2.45 guilders	7.39 crowns	140.05 pesetas	7.14 crowns	1.80 francs	0.682 pound	2.17 marks
1985	59.38 francs	8.99 francs	1909 lire	3.32 guilders	8.60 crowns	170.04 pesetas	8.60 crowns	2.46 francs	0.772 pound	2.94 marks
1984	57.78 francs	8.74 francs	1757 lire	3.21 guilders	8.16 crowns	160.76 pesetas	8.27 crowns	2.35 francs	0.748 pound	2.85 marks

Source: International Monetary Fund

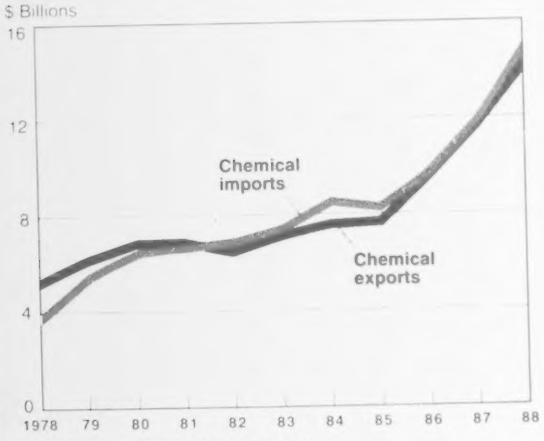
6

Foreign Chemical Industries—**Japan**

The Japanese economy remained healthy last year, with economic expansion continuing into 1989. Industrial production, for example, was up a stout 10%, an increase about three times greater than in 1987.

As a result, strong domestic demand kept the chemical industry busy throughout the year. Paced by organic chemicals and plastics, chemical output was 8% higher than in 1987. And many of the major Japanese chemical producers racked up markedly wider profit margins during their most recent fiscal year. Although the deficit in Japan's trade balance in chemicals widened just a bit—not surprising considering the strength of the yen—it was not enough in the red to cause alarm.

Slight deficit continues for chemical trade



Source: Ministry of International Trade & Industry

INDUSTRY TRENDS: **Output gains**

Production index, 1985 = 100	1988	1987	1986	1985	Change 1987-88
All manufacturing	113.1	103.2	99.8	100.0	10%
All chemicals	120.0	111.1	103.2	100.0	8
Inorganic chemicals and pigments	108.4	100.9	98.5	100.0	7
Alkalies and chlorine	110.5	103.6	98.5	100.0	7
Organic chemicals	115.9	105.4	98.5	100.0	10
Petrochemicals	118.0	107.6	100.5	100.0	10
Aromatics	115.9	107.1	99.9	100.0	8
Cyclic intermediates and dyes	121.2	110.9	101.3	100.0	9
Plastics	120.6	109.9	102.5	100.0	10
Synthetic fibers	95.4	94.6	95.9	100.0	1
Synthetic rubber	112.2	102.9	99.6	100.0	9
Fertilizer	88.5	91.6	93.3	100.0	−3
Textile materials	117.8	110.7	103.1	100.0	6
Medicinals and drugs	134.8	123.1	108.8	100.0	10

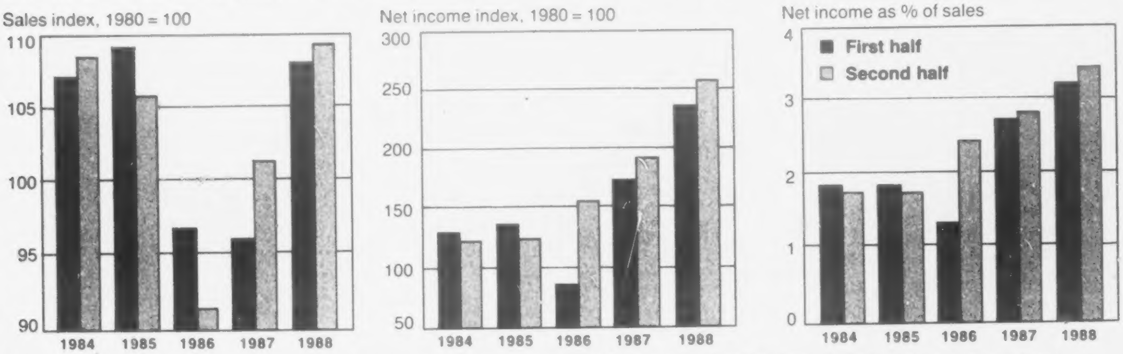
Source: Ministry of International Trade & Industry

PRODUCTION: **Up for most chemicals**

Thousands of metric tons unless otherwise indicated	1988	1987	1986	1985	Change 1987-88
INORGANIC CHEMICALS					
Ammonia	1817	1784	1794	1981	2%
Ammonium chloride	299	332	364	373	−10
Ammonium sulfate	1834	1804	1784	1837	2
Calcium carbide	342	354	399	441	−3
Calcium superphosphate	476	499	514	529	−5
Carbon black	720	635	616	632	13
Chlorine, liquid	979	911	881	926	7
Hydrochloric acid	565	543	549	549	4
Nitrogen, millions of cu m	6940	6452	6293	6220	8
Oxygen, millions of cu m	7707	6878	6786	7388	12
Sodium carbonate	1083	1098	1022	1057	−1
Sodium hydroxide	3508	3227	3077	3075	9
Sodium silicate	721	664	603	594	9
Sulfuric acid	6766	6541	6561	6580	3
Titanium dioxide	258	238	223	217	8
ORGANIC CHEMICALS					
Acetaldehyde	333	285	254	271	17
Acetic acid	402	377	300	344	7
Acetone	289	260	228	237	11
Acrylonitrile	600	573	546	541	5
Benzene[a]	2374	2226	2071	2084	7
Butadiene	780	707	656	639	10
Butanol	276	259	248	258	7
Caprolactam	493	470	448	455	5
Cyclohexane	561	557	515	524	1
Dioctyl phthalate	273	261	257	241	5
Ethylene	5162	4585	4291	4224	13
Ethylene dichloride	2301	2051	1908	1901	12
Ethylene glycol	349	313	339	440	12
Ethylene oxide	510	484	489	554	5
Methanol	141	181	221	254	−22
Octanol	273	257	235	230	6
Phenol	358	308	260	262	16
Phthalic anhydride[a]	171	172	163	162	−1
Propylene	3682	3370	3167	2980	9
Propylene glycol	265	236	223	219	12
Styrene	1757	1559	1417	1418	13
Terephthalic acid	1150	1048	935	854	10
Toluene	1018	1006	805	803	1
Toluene diisocyanate	96	91	86	84	5
Urea	791	729	778	929	9
Xylene	1988	1767	1570	1523	13
PLASTICS					
Phenolic resins	356	332	313	325	7
Polyethylene	2380	2181	2066	2027	9
Polypropylene	1559	1405	1333	1304	11
Polystyrene	1891	1735	1598	1599	9
Polyvinyl chloride	1838	1663	1540	1550	11
SYNTHETIC RUBBER	1299	1192	1150	1158	9

[a] Petroleum-based product only. Source: Ministry of International Trade & Industry

Chemical sales are only moderately higher, but profits have swelled, fattening profit margins



Note: Based on results of 12 leading Japanese chemical companies: Asahi Chemical, Dainippon Ink & Chemicals, Hitachi Chemical, Mitsubishi Kasei, Mitsubishi Petrochemical, Mitsui Toatsu Chemicals, Sekisui Chemical, Showa Denko, Sumitomo Chemical, Takeda Chemical Industries, Teijin, and Toray Industries. The fiscal year for most, but not all, of these companies ends March 31. **Source:** Toyo Keizai Shinposha

COMPANY RESULTS Profitability continues to improve for Japanese chemical producers

$ Millions	Net sales	Net income	Profit margin	Total assets	Employees (thousands)
Asahi Chemi[illegible]					
1988	$6384	$219.4	3.4%	$6410	15.4
1987	5357	141.0	2.6	5241	15.6
1986	4351	84.6	1.9	4361	15.9
1985	3910	73.3	1.9	3661	15.9
Mitsubishi K[illegible]					
1988	$6132	$124.9	2.0%	$6973	8.8
1987	4360	90.4	2.1	6002	8.9
1986	3775	42.0	1.1	5014	8.5
1985	3963	33.1	0.8	4016	8.2
Takeda Chem[illegible]					
1988	$4567	$269.4	5.9%	$5358	10.8
1987	3777	219.6	5.8	4628	10.8
1986	2951	133.6	4.5	3599	10.8
1985	2331	98.4	4.2	2612	11.0
Sumitomo [illegible]					
1988	$4341	$116.4	2.7%	$5806	7.7
1987	3609	78.6	2.2	4615	7.7
1986	3085	29.3	1.0	3949	7.6
1985	3219	38.9	1.2	3277	7.1
Toray [illegible]					
1988	$4317	$134.7	3.1%	$5528	10.0
1987	3789	113.5	3.0	4854	10.6
1986	3250	67.1	2.1	3947	11.7
1985	3177	78.2	2.5	3326	12.6
Sekisui Chem[illegible]					
1988	$3936	$141.4	3.6%	$2919	5.2
1987	3089	84.6	2.7	2555	5.3
1986	2229	31.0	1.4	1732	6.3
1985	1769	22.5	1.3	1439	6.2

$ Millions	Net sales	Net income	Profit margin	Total assets	Employees (thousands)
[illegible]					
1988	$3679	$ 71.3	1.9%	$4299	5.1
1987	2908	38.8	1.3	3881	5.0
1986	2116	22.1	1.0	3163	4.8
1985	2066	20.1	1.0	2738	4.6
[illegible]					
1988	$3440	$ 62.2	1.8%	$4074	6.7
1987	2923	43.7	1.5	3366	6.6
1986	2336	32.8	1.4	2214	6.3
1985	2102	26.4	1.3	1722	6.2
[illegible]					
1988	$3082	$ 83.5	2.7%	$3936	5.4
1987	2543	43.5	1.7	3004	5.6
1986	2110	23.0	1.1	2599	5.6
1985	2102	14.7	0.7	2242	5.4
[illegible]					
1988	$2654	$160.0	6.0%	$3493	2.9
1987	2022	64.7	3.2	2843	2.8
1986	1642	25.7	1.6	2073	2.5
1985	2139	22.4	1.1	1939	2.4
[illegible]					
1988	$2438	$136.5	5.6%	$3823	5.8
1987	2167	109.3	5.0	3391	6.2
1986	2039	72.0	3.5	2600	6.4
1985	2102	70.9	3.4	2210	7.0
[illegible]					
1988	$2158	$ 28.2	1.3%	$1261	5.0
1987	1748	20.7	1.2	1056	4.9
1986	1387	14.1	1.0	891	5.0
1985	1123	9.3	0.8	720	4.9

Note: Monetary statistics are converted from yen to U.S. dollars on the basis of $1.00 equals: 1988, 128.1 Y; 1987, 142.9 Y; 1986, 166.9 Y; 1985, 204.6 Y. Year-to-year changes in sales, net income, and assets are affected by these fluctuations in the currency exchange rate. **a** Fiscal year ends March 31. **b** Fiscal year ends March 31 for 1988, Jan. 31 for 1987, 1986, and 1985. **c** Fiscal year ends Dec. 31. **Source:** Toyo Keizai Shinposha

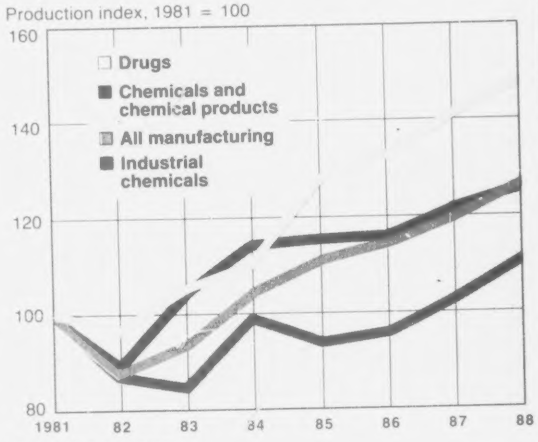
6 Foreign Chemical Industries — Canada

For the Canadian chemical industry, 1988 was a banner year. Hefty demand in home markets, good growth in exports, and higher selling prices for many major products, especially petrochemicals and plastics, combined to bolster companies' financial performance.

It also was a year that witnessed some major shifts in the industry's corporate structure. In April, to better integrate its worldwide chemical business, Britain's ICI acquired sole ownership of C-I-L Inc., the Canadian subsidiary in which it has long held a majority interest, and began a drastic revamping of the Canadian firm's operations by selling off several C-I-L activities that it deemed unessential. And last fall, Nova Corp. of Alberta acquired the major operations of Polysar Energy & Chemical, in the process becoming a world-scale producer of petrochemicals. On the other hand, early this year a bid by Hoechst Celanese, the U.S. arm of West Germany's Hoechst, to buy up the shares in Celanese Canada that it does not already hold failed when too few of the minority shareholders tendered their stock.

Note on currency conversion: Monetary statistics in this section have been converted from Canadian dollars to U.S. dollars on the basis of $1.00 U.S. equals: 1988, $1.231 Canadian; 1987, $1.322 Canadian; 1986, $1.391 Canadian; 1985, $1.362 Canadian; 1984, $1.308 Canadian; 1983, $1.244 Canadian.

Expansion continues for chemical output



Source: Statistics Canada

COMPANY RESULTS: Profits continue strong

$ Millions (U.S.)	Sales	Net income[a]	Profit margin	Capital expenditures	Employees (thousands)
Celanese Canada					
1988	$ 330.8	$ 39.7	12.0%	$ 19.9	2.1
1987	265.5	21.5	8.1	16.1	2.1
1986	248.2	13.5	5.5	9.0	2.1
1985	247.7	9.3	3.7	11.2	2.1
Du Pont Canada					
1988	$1130.9	$ 81.2	7.3%	$ 86.6	4.0
1987	1021.4	68.5	6.7	47.9	4.2
1986	893.7	43.4	4.9	67.9	4.6
1985	870.7	15.1	1.7	52.4	4.9
Nova Corp. of Alberta					
1988	$3202	$344	10.8%	$357	na
1987	1755	135	7.7	151	na
1986	1928	78	4.0	234	na
1985	2457	(60)[b]	—	284	na
Union Carbide Canada					
1988	$ 461.3	$ 34.3	7.4%	$ 45.0	2.8
1987	318.4	19.4	6.1	26.1	2.3
1986	258.1	14.5	5.6	29.7	3.3
1985	264.8	11.7	4.4	16.4	3.8

a Excludes extraordinary gains and losses. b Net loss. **na** = not available.

PRODUCTION: Higher for most chemicals

Thousands of metric tons	1988	1987	1986	1985	Change 1987–88
INORGANIC CHEMICALS					
Ammonia	4010	3512	3540	3620	14%
Ammonium nitrate	981	844	948	1075	16
Ammonium phosphate	986	941	1149	1301	5
Carbon black	181	172	154	173	5
Chlorine	1664	1635	1536	1424	2
Hydrochloric acid	180	164	153	158	9
Nitric acid	907	900	1024	1128	1
Phosphoric acid, 100% P_2O_5	475	464	554	629	2
Sodium chlorate	503	432	373	336	17
Sodium hydroxide	1720	1770	1696	1589	−3
Sulfuric acid	3805	3437	3536	3890	11
Zinc oxide	62	44	38	na	40
ORGANIC CHEMICALS					
Benzene	695	720	635	691	−3
Butadiene	183	167	146	132	9
Butylene	148	156	142	133	−5
Ethylene	2346	2140	1909	1745	10
Formaldehyde	123	122	117	na	1
Methanol	2101	1627	1403	na	29
Propylene	669	628	628	647	7
Toluene	417	396	393	472	5
Urea	2372	2142	2330	2033	11
Xylenes	399	345	356	415	16
PLASTICS					
Polyesters, unsaturated	43	47	37	36	−9
Polyethylene, high density	311	270	242	229	15
Polyethylene, low density	1105	1021	887	733	8
Polystyrene[a]	216	197	186	178	9

a Includes acrylonitrile-butadiene-styrene resins. **na** = not available. **Source:** Statistics Canada

SHIPMENTS: Up sharply for organic chemicals and plastics last year

$ Millions (U.S.)	1988	1987	1986	1985	1984	1983	Change 1987-88[a]
All manufacturing	$234,398	$204,019	$179,420	$179,177	$174,373	$163,192	7%
Chemicals and chemical products	18,306	15,239	13,066	12,898	12,821	12,613	12
Industrial chemicals, inorganic	1,888	1,715	1,651	1,605	1,757	1,750	[illegible]
Industrial chemicals, organic	5,425	3,978	2,725	2,833	2,966	3,102	[illegible]
Plastics and synthetic resins	2,098	1,745	1,396	1,317	1,331	1,302	12
Pharmaceuticals and medicinals	2,449	2,094	1,664	1,536	1,468	1,336	9
Adhesives	124	119	111	98	94	92	−3
Paint and varnish	1,303	1,120	951	881	815	784	8
Soaps and cleansers	1,112	995	1,038	1,028	962	940	4
Toilet preparations	879	758	640	626	614	597	8
Printing ink	219	190	209	184	183	172	7
Synthetic fibers	784	695	586	563	568	607	5
Plastic products	4,323	3,620	2,890	2,700	2,633	2,448	11

a In Canadian dollars. **Source:** Statistics Canada

CHEMICAL IMPORTS: A fourth are organics

$ Millions (U.S.)	1988	1987	1986	1985
Inorganic chemicals	$ 566	$ 396	$ 377	$ 374
Organic chemicals	1561	1270	1162	1107
Fertilizers and fertilizer materials	197	158	143	152
Synthetic and reclaimed rubber	228	202	169	160
Plastic materials	1097	831	702	651
Plastic film and sheet	392	372	306	278
Other plastic shapes and forms	431	261	233	214
Dyes, except dyeing intermediates	86	71	58	49
Pigments, lakes, and toners	112	115	95	78
Paints and related products	195	176	132	127
Other chemical products	960	857	822	807
TOTAL	**$5825**	**$4708**	**$4199**	**$3997**
Imports from U.S.	**$4330**	**$3586**	**$3145**	**$3034**
U.S. share	74%	76%	75%	76%

Source: Statistics Canada

CHEMICAL EXPORTS: Organics, plastics soar

$ Millions (U.S.)	1988	1987	1986	1985
Chemical elements	$ 199	$ 167	$ 173	$ 158
Other inorganic chemicals	1135	908	882	828
Organic chemicals	1518	1029	826	995
Fertilizers and fertilizer materials	1351	960	835	946
Synthetic rubber and plastic materials	1265	858	632	587
Plastics, basic shapes and forms	381	380	327	238
Other chemical products	376	338	294	236
TOTAL	**$6226**	**$4639**	**$3968**	**$3988**
Exports to U.S.	**$3927**	**$2938**	**$2625**	**$2669**
U.S. share	63%	63%	66%	67%

Source: Statistics Canada

TRADE BALANCE: Overall surplus down . . .

$ Billions (U.S.)	1988	1987	1986	1985	1984
Total exports	$109.0	$91.8	$83.9	$85.3	$83.8
Total imports	106.5	87.9	80.9	77.1	73.2
Trade balance	2.5	3.9	3.0	8.2	10.6

. . . but chemical trade becomes positive

$ Millions (U.S.)	1988	1987	1986	1985	1984
Chemical exports	$6226	$4639	$3968	$3988	$4054
Chemical imports	5825	4708	4199	3997	3986
Chemical trade balance	401	−69	−232	−9	68

Source: Statistics Canada

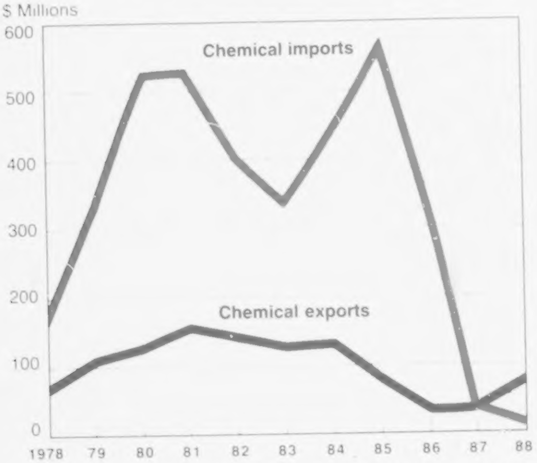
PRICES: Big hikes in organics, plastics

Price index, 1981 = 100	1988	1987	1986	Change 1987-88
All commodities	127.9	122.8	119.6	4%
Chemicals and chemical products	131.3	119.7	116.0	10
Inorganic industrial chemicals	116.0	111.6	113.4	4
Sulfuric acid	133.6	130.6	125.2	2
Chlorine	130.8	130.4	128.5	0
Ammonia	79.6	78.9	89.7	1
Organic industrial chemicals	116.9	95.0	90.0	23
Benzene-toluene-xylene	67.4	70.1	68.5	−4
Olefins	114.7	79.5	76.9	44
Synthetic resins	141.0	118.0	110.4	19
Polyethylene[a]	147.1	105.6	96.5	39
Polystyrene	146.4	122.7	93.9	19
Thermosets	133.0	116.1	108.3	15
Synthetic fibers	103.5	101.7	100.1	2
Agricultural chemicals	112.9	111.8	111.4	1
Mixed fertilizers	107.2	97.9	97.3	9
Pharmaceuticals	169.4	160.3	150.0	6
Paint and varnish	134.9	130.5	129.4	3
Soaps and cleansers	132.3	127.7	123.3	4
Toilet preparations	159.3	152.2	146.3	5
Pigments, lakes, and toners	126.8	120.2	119.5	5
Inks	112.4	110.7	111.4	2

a Includes both high and low density. **Source:** Statistics Canada

6 Foreign Chemical Industries — **Mexico**

Pemex hikes exports and slashes imports



Note: Trade by Pemex of primary petrochemicals only. Does not include secondary chemicals. Import statistics for 1987 and 1988 reflect the fact that private companies, as well as Pemex, can now import primary petrochemicals directly.
Source: Petroleos Mexicanos

IMPORTS: Pemex has slashed foreign buying

Thousands of metric tons[a]	1988	1987	1986	1985	1984
Acetaldehyde	0	0	26	70	70
Acrylonitrile	0	0	36	50	34
Ammonia	0	151	13	39	0
Butadiene	0	0	44	97	67
Cyclohexane	0	0	19	33	26
Dichloroethane	0	0	0	0	57
Dodecylbenzene	0	0	5	39	49
Ethylbenzene	2	3	0	6	16
Ethylene oxide	0	0	2	48	11
Isopropyl alcohol	0	0	26	50	44
Perchloroethylene	0	0	15	14	15
Polyethylene, high density	2	1	82	42	19
Polyethylene, low density	2	1	76	127	63
Propylene	20	22	26	26	26
Propylene tetramer	4	6	47	19	12
Styrene	0	0	49	112	93
Toluene	0	0	47	43	37
Vinyl chloride	0	0	100	162	109
o-Xylene	0	0	7	9	0
p-Xylene	0	0	114	179	119

[a] Imports by Petroleos Mexicanos (Pemex) of primary petrochemicals; see note for graph above. **Source:** Pemex

PRODUCTION: Up for most petrochemicals

Thousands of metric tons[a]	1988	1987	1986	1985	Change 1987-88
Acetaldehyde	156	158	136	145	−1%
Acrylonitrile	61	58	54	49	5
Ammonia, anhydrous	2515	2121	1949	2261	19
Benzene	271	282	222	178	−4
Butadiene	12	21	18	18	−43
Cyclohexane	42	52	39	32	−19
Cumene	48	38	42	39	26
Dichloroethane	330	326	271	193	1
Dodecylbenzene	111	98	103	61	13
Ethane	2927	2518	2550	1905	16
Ethylbenzene	159	152	91	46	5
Ethylene	916	804	767	670	14
Ethylene oxide	102	95	114	71	7
Hexane	70	98	101	98	−29
Hydrochloric acid	118	117	83	63	1
Isopropyl alcohol	14	17	11	14	−18
Methanol	201	191	182	192	5
Nitrogen	62	49	49	46	27
Oxygen	241	179	206	211	35
Polyethylene, high density	82	76	69	67	8
Polyethylene, low density	317	275	242	160	15
Propylene	281	257	232	207	9
Propylene tetramer	108	76	51	31	42
Styrene	131	121	69	33	8
Sulfur, recovered	510	501	456	475	2
Toluene	309	313	238	220	−1
Vinyl chloride	175	179	141	108	−2
m- and *p*-Xylene	322	313	231	247	3
o-Xylene	68	68	42	44	0

[a] Production by Petroleos Mexicanos (Pemex) of primary petrochemicals. **Source:** Pemex

DOMESTIC SALES: Few big changes last year

Thousands of metric tons[a]	1988	1987	1986	1985	Change 1987-88
Acetaldehyde	153	157	150	199	−3%
Acrylonitrile	62	58	91	96	7
Ammonia, anhydrous	1936	1909	1857	1804	1
Benzene	13	14	13	17	−7
Butadiene	11	18	68	110	−39
Cyclohexane	41	51	55	62	−20
Dodecylbenzene	107	92	102	100	16
Ethylene oxide	97	94	109	118	3
Hexane	49	48	37	48	2
Isopropyl alcohol	13	16	42	61	−9
Methanol	185	160	176	176	16
Polyethylene, high density	82	78	119	134	5
Polyethylene, low density	307	296	282	266	4
Styrene	126	119	123	140	6
Sulfur	508	497	462	457	2
Toluene	87	77	90	97	13
Vinyl chloride	172	173	261	275	−1
o-Xylene	67	63	43	38	6
p-Xylene	193	203	226	268	−5

[a] Domestic sales by Petroleos Mexicanos (Pemex) of primary petrochemicals. **Source:** Pemex

Foreign Chemical Industries — **Eastern Europe**

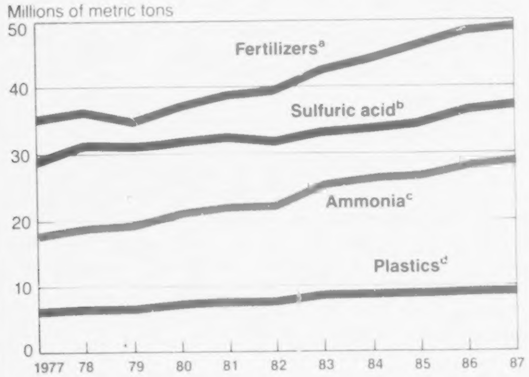
Last year, overall industrial output in Eastern Europe and the Soviet Union rose nearly 4%, about the same as in 1987 but well below the expansion of almost 5% in 1986. Growth also fell short of the region's target of 4.3% for 1988. Growth in chemical production in 1988 was merely 2% in Czechoslovakia and practically nil in Hungary, reflecting the general industrial slowdown in both countries. The Soviet chemical industry grew more slowly than in recent years, as well. Poland's industry showed the fastest growth in the region.

MAN-MADE FIBERS: **Strong growth for noncellulosics in Soviet Union and Hungary**

Production, thousands of metric tons	1987	1986	1985	1984	Change 1986-87
NONCELLULOSIC FIBERS					
Bulgaria	83	81	71	68	2%
Czechoslovakia	132	128	115	107	3
East Germany	161	159	146	144	1
Hungary	24	21	22	21	12
Poland	151	148	149	144	2
Romania	202	200	197	174	1
U.S.S.R.	836	758	713	658	10
TOTAL	**1588**	**1495**	**1412**	**1317**	6%
CELLULOSIC FIBERS					
Bulgaria	43	42	42	41	1%
Czechoslovakia	62	62	60	59	1
East Germany	128	128	168	170	1
Hungary	6	6	6	7	2
Poland	73	72	71	76	1
Romania	66	64	62	60	3
U.S.S.R.	592	589	586	602	0
TOTAL	**970**	**962**	**994**	**1014**	1%

a Excludes olefins and glass fiber. **Source:** Fiber Economics Bureau

Output edges higher for major chemical products in Eastern Europe



Note: Data for U.S.S.R., Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, and Romania. **a** As N, P_2O_5, and K_2O. **b** 100% H_2SO_4. **c** Nitrogen content. **d** Including resins for man-made fibers in U.S.S.R. **Sources:** Central Intelligence Agency, Department of Agriculture, PlanEcon Inc., official national statistics from state central statistical bureaus

PRODUCTION GROWTH: **Slower for chemicals in the Soviet Union**

% annual change in gross output	1988	1987	1986	1985	1984
U.S.S.R. and East Europe					
All industry	3.9%	3.8%	4.8%	3.9%	4.3%
Bulgaria					
All industry	5.1	4.2	4.0	3.2	4.2
Chemicals	5.0	5.1	4.9	3.6	8.2
Czechoslovakia					
All industry	2.0	2.5	3.2	3.5	4.0
Chemicals	1.9	3.2	4.0	5.1	4.5
East Germany					
All industry[a]	3.7	3.2	3.8	4.4	4.2
Chemicals	4.0	2.6	2.2	3.7	4.3
Hungary					
All industry	−0.4	3.5	1.9	0.7	3.2
Chemicals[b]	0.3	5.8	1.1	0.8	4.4
Poland					
All industry	5.4	3.4	4.7	4.5	5.2
Chemicals	6.5	4.3	4.2	3.0	5.0
Romania					
All industry	3.6	4.5	7.7	4.9	6.7
Chemicals	3.0	−4.1	8.3	0.3	8.1
U.S.S.R.					
All industry[c]	3.9	3.9	4.9	3.9	4.1
Chemicals[c]	3.8	4.4	6.3	5.0	5.1
All industry[d]	na	1.5[e]	2.6	1.8	2.5
Chemicals[d]	na	3.2[e]	4.6	4.1	3.2

a Industrial commodity production. **b** For state and cooperative industry only. **c** Figures based on official Soviet statistics. **d** Figures based on Central Intelligence Agency estimates, giving lower results because of postulated upward bias in official figures. **e** Preliminary figure. **na** = not available. **Sources:** United Nations Economic Commission for Europe and state central statistical bureaus, Central Intelligence Agency

AGRICULTURAL CHEMICALS: **Supplies up modestly for fertilizers in the Soviet Union**

Thousands of metric tons	1988	1987	1986	1985	1984
Bulgaria					
Fertilizer supply[a]	na	745	808	865	938
Pesticide supply[b]	na	28.5	36.5	35.6	35.6
Czechoslovakia					
Fertilizer supply[a]	na	1,557	1,689	1,734	1,749
East Germany					
Fertilizer supply[a]	na	1,664	1,642	1,639	1,565
Pesticide supply[b]	na	29.9	29.4	26.7	26.0
Hungary					
Fertilizer supply[a]	na	1,373	1,383	1,338	1,524
Poland					
Fertilizer supply[a]	3,296	3,583	3,413	3,280	3,424
Pesticide supply[b]	23.0	18.4	14.5	12.4	11.1
Romania					
Fertilizer supply[a]	na	na	1,386	1,374	1,289
U.S.S.R.					
Fertilizer supply[a]	27,100	27,412	26,514	25,395	23,080
Nitrogen[a]	11,700[c]	11,787	11,475	10,950	10,279
Phosphate[a,d]	8,487[c]	8,564	8,354	7,615	6,625
Potassium[a]	6,904[c]	7,052	6,677	6,822	6,167

a Nutrient content basis, as N, P_2O_5, or K_2O. **b** On basis of active substance. **c** Estimated. **d** Includes ground phosphate rock. **na** = not available. **Sources:** Department of Agriculture, Central Intelligence Agency, official national statistics from state central statistical bureaus

Foreign Chemical Industries — **Eastern Europe**

PRODUCTION: Growth has been limited in recent years for some major chemicals

Thousands of metric tons, unless otherwise noted	1988[a]	1987	1986	1985	1984
U.S.S.R.					
Sulfuric acid	na	28,531	27,847	26,037	25,338
Mineral fertilizers[b]	37,100	36,334	34,737	33,194	30,808
Nitrogen[b]	16,000[a]	15,743	15,221	14,223	13,328
Phosphate[b,c]	9,901[a]	9,697	9,279	8,596	7,695
Potassium[b]	11,190[a]	10,888	10,228	10,367	9,776
Synthetic ammonia[d]	na	20,470	19,590	18,232	17,677
Plastics[e]	5,876	5,486	5,345	5,019	4,819
Sodium hydroxide	na	3,288	3,229	3,056	2,972
Ethylene	na	2,930	2,799	2,667	2,543
Methanol	na	3,284	3,219	2,850	2,467
Synthetic rubber[f]	na	2,360	2,320	2,125	2,085
Pesticides[g]	na	327	332	348	343
BULGARIA					
Sulfuric acid	780	689	807	810	908
Mineral fertilizers[b]	767	571	580	640	690
Nitrogen[b]	588	443	448	469	479
Phosphate[b]	178	128	132	172	211
Synthetic ammonia[d]	na	1,070	1,091	1,138	1,138
Plastics	na	312	420	406	430
Sodium hydroxide	129	104	138	151	163
Synthetic rubber	na	25	25	26	26
Pesticides[g]	na	15	15	18	20
CZECHOSLOVAKIA					
Sulfuric acid	1,249	1,264	1,292	1,297	1,246
Mineral fertilizers[b]	na	984	1,041	962	1,136
Nitrogen[b]	596	596	614	526	576
Phosphate[b,c]	313	277	307	310	344
Potassium[b,g]	na	111	120	126	216
Synthetic ammonia[d]	na	950	930	994	827
Plastics	1,192	1,152	1,140	1,103	1,039
Sodium hydroxide	na	338	335	331	329
Synthetic rubber	na	75	76	70	71
Pesticides[g]	na	18	20	19	17
EAST GERMANY					
Sulfuric acid	na	866	883	883	885
Mineral fertilizers[b]	na	5,119	5,046	4,842	4,732
Nitrogen[b]	1,383	1,318	1,252	1,078	959
Phosphate[b,c]	na	291	309	299	308
Potassium[b]	na	3,510	3,485	3,465	3,465
Synthetic ammonia[d]	na	1,179	1,197	1,210	1,207
Plastics	na	1061	1045	1048	1056
Sodium hydroxide	na	577	638	667	694
Synthetic rubber	na	85	118	140	152
Pesticides[g]	na	59	62	60	58
HUNGARY					
Sulfuric acid	512	573	543	520	549
Mineral fertilizers[b]	na	1067	1040	1066	1100
Nitrogen[b]	na	667	655	684	675
Phosphate[b]	na	283	267	252	286
Potassium[b,h]	na	117	118	130	139
Synthetic ammonia[d]	na	785	763	790	813
Plastics	581	539	426	389	385
Ethylene	264	270	269	271	265
Sodium hydroxide[i]	202	201	202	194	194
POLAND					
Sulfuric acid	3166	3149	2965	2863	2769
Mineral fertilizers[b]	na	2622	2526	2270	2356
Nitrogen[b]	1622	1543	1445	1254	1369
Phosphate[b]	962	943	948	889	869
Potassium[b,h]	na	137	133	127	118
Synthetic ammonia[d]	na	1791	1747	1490	1499
Plastics	720	641	632	603	601
Sodium hydroxide	444	425	427	414	379
Ethylene	na	276	279	261	256
Synthetic rubber	127	117	116	126	119
ROMANIA					
Sulfuric acid	na	1693	1971	1835	1915
Mineral fertilizers[b]	na	2897	3278	3097	3073
Nitrogen[b]	na	na	2315	2197	2212
Phosphate[b]	na	na	849	788	765
Synthetic ammonia[d]	na	2784	3037	2876	2857
Plastics	na	638	664	628	655
Sodium hydroxide	na	817	846	814	805
Ethylene	na	319	312	307	317
Synthetic rubber	164	152	162	156	159
Pesticides[g]	na	41	53	53	53

a Approximate figures or estimates. **b** Nutrient content basis, as N, P_2O_5, or K_2O. **c** Including production of ground phosphate rock for direct applications and phosphate animal feeds. **d** Nitrogen content. **e** Including resins for man-made fibers. **f** Estimated. **g** On basis of active substance. **h** Imported potash added to domestically produced nitrogen and phosphate to form multinutrient fertilizer. **i** Including regenerated NaOH. **na** = not available. **Sources:** Central Intelligence Agency, Department of Agriculture, PlanEcon, Inc., official national statistics from state central statistical bureaus.

SOVIET FOREIGN TRADE: Surplus sharply lower as imports swell

$ Millions	1988[a]	1987[b]	1986	1985	1984	1983	1982	1981	1980	1979	1978
Exports[b]	$108,727	$107,664	$97,053	$87,196	$91,495	$91,652	$87,168	$79,380	$76,437	$64,912	$52,435
Imports[b]	105,365	95,969	88,874	83,315	80,409	80,445	77,846	73,194	68,473	57,958	50,798
Trade balance	3,362	11,695	8,179	3,881	11,086	11,207	9,322	6,186	7,964	6,954	1,637
Chemical exports[b]	na	na	2,770	2,837	2,707	2,307	2,203	2,275	2,025	1,606	1,284
Chemical imports[b]	na	na	3,990	3,774	3,256	3,216	3,028	3,211	3,275	2,803	2,188
Chemical trade balance	na	na	−1,220	−937	−549	−909	−825	−1,651	−1,250	−1,197	−904

a Preliminary values. **b** Free on board. **na** = not available. **Sources:** Central Intelligence Agency, U.S.-U.S.S.R. Trade & Economic Council, based on official Soviet statistics and exchange rates.

6 Foreign Chemical Industries — Western Pacific

SOUTH KOREA

INDUSTRY TRENDS: 1988 brought big gains

Index, 1985 = 100	1988	1987	1986	1985	Change 1987-88
Chemicals, petroleum, coal, rubber, and plastic products					
Production	153.0	129.0	113.4	100.0	19%
Shipments	147.6	124.7	111.8	100.0	18
Inventories	128.5	112.8	109.9	100.0	14
Industrial chemicals					
Production	149.7	127.3	111.9	100.0	18
Shipments	146.1	128.1	113.9	100.0	14
Inventories	116.9	104.3	99.2	100.0	12
Other chemical products					
Production	171.9	131.4	107.6	100.0	31
Shipments	166.3	133.8	109.5	100.0	24
Inventories	161.9	122.0	113.8	100.0	33
Rubber products					
Production	155.0	138.0	122.9	100.0	12
Shipments	155.0	137.4	121.4	100.0	13
Inventories	138.9	119.3	114.3	100.0	16
Plastic products					
Production	173.2	159.2	130.4	100.0	9
Shipments	158.1	154.5	127.2	100.0	2
Inventories	131.9	137.6	126.3	100.0	−4
All manufacturing					
Production	164.7	144.7	121.6	100.0	14
Shipments	162.2	143.2	121.1	100.0	13
Inventories	134.8	118.6	107.9	100.0	14

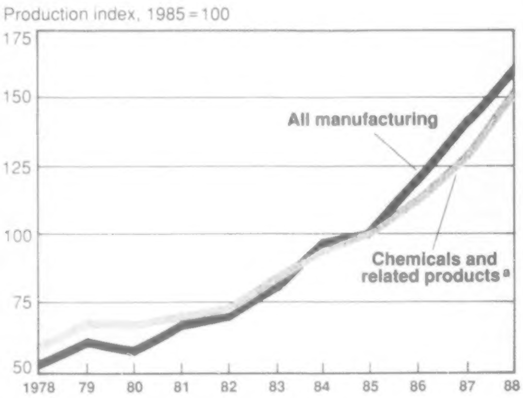
Source: Bureau of Statistics of the Korean Economic Planning Board

FOREIGN TRADE: Chemical deficit widened

$ Millions	1988	1987	1986	1985
Exports[a]	$60,696	$47,281	$34,714	$30,283
Imports[b]	51,811	41,020	31,584	30,136
Trade balance	8,886	6,261	3,130	−853
Chemical exports	1,879	1,321	1,068	936
Chemical imports	6,282	4,595	3,495	2,789
Chemical trade balance	−4,404	−3,274	−2,427	−1,853

a Free on board. **b** Includes cost, insurance, freight. **Source:** Korean Office of Customs Administration

South Korea's industrial expansion continues to surge



a Includes petroleum, coal, rubber, and plastic products
Source: Bureau of Statistics of Korean Economic Planning Board

PRODUCTION: Some sharp increases

Thousands of metric tons	1988	1987	1986	1985	Change 1987-88
Complex fertilizers	2038	1966	1872	1960	4%
Urea fertilizers	1000	911	812	839	10
Ethylene	609	576	534	562	6
Polyvinyl chloride	455	451	472	411	1
Polyethylene	572	469	376	353	22
Polyester fibers	593	503	426	390	16
Polypropylene	518	348	263	259	49
Propylene	351	328	307	318	7
Sodium hydroxide	311	262	259	235	19
Benzene	308	339	301	216	−9
Synthetic detergents	275	211	167	139	31

Source: Bureau of Statistics, Korean Economic Planning Board

AUSTRALIA

PRODUCTION: Higher for most chemicals

Thousands of metric tons	1988[a]	1987[a]	1986[a]	1985[a]	Change 1987-88
Chemicals					
Hydrochloric acid, 100%	68	62	54	58	10%
Nitric acid, 100%	204	203	193	200	0
Sulfuric acid, 100%	1816	1678	1788	1773	8
Ammonium sulfate	179	165	205	243	8
Superphosphate[b]	3194	2769	2610	2586	15
Plastics and resins	990	905	885	na	9
Synthetic detergents	271	254	239	226	7
Unsupported plastics film, sheeting	186	175	162	157	6
Polyethylene[c]	137	128	120	118	7
Polyvinyl chloride[d]	16	16	15	14	−4

a Year ending June 30. **b** Includes double and triple superphosphates and ammonium phosphate expressed in terms of single phosphate (22% P_2O_5 equivalent). **c** Low and high density. **d** Including copolymers. **na** = not available. **Source:** Australian Bureau of Statistics

FOREIGN TRADE: Chemical trade deficit up

$ Millions	1988[a]	1987[a]	1986[a]	1985[a]
Exports[b,c]	$29,837	$23,724	$22,969	$23,104
Imports[d]	29,579	24,546	24,288	22,591
Trade balance	258	−822	−1,319	513
Chemical exports[b,c]	650	440	415	422
Medicinal products	149	110	103	95
Chemical imports[d]	3,117	2,302	2,119	1,982
Organic chemicals	806	584	537	523
Inorganic chemicals	378	213	174	147
Medicinal products	472	337	275	228
Chemical trade balance	−2,467	−1,862	−1,704	−1,560

Note: Monetary statistics converted from Australian to U.S. dollars on basis of $A1.00 equals: 1985, $0.7777; 1986, $0.7006; 1987, $0.6630; 1988, $0.7287. **a** Year ending June 30. **b** Free on board. **c** Includes re-exports. **d** Values for customs purposes, free-on-board basis. **Source:** Australian Department of Foreign Affairs & Trade

6

Foreign Chemical Industries — Eastern Asia

CHINA

PRODUCTION: Further expansion during 1988 paced by ethylene

Thousands of metric tons, unless otherwise noted	1988	1987	1986	1985	Change 1987-88
Fertilizer[a]	17,675	17,032	13,966	13,222	4%
Synthetic ammonia	19,725	19,486	17,195	17,212	1
Sulfuric acid	10,981	9,620	7,631	6,764	14
Sodium hydroxide	2,925	2,735	2,270	2,353	7
Sodium carbonate	2,593	2,372	2,150	2,011	9
Plastics	1,552	1,432	1,322	1,234	8

Thousands of metric tons, unless otherwise noted	1988	1987	1986	1985	Change 1987-88
Man-made fibers	1,284	1,157	1,016	945	11%
Synthetic detergents	1,290	1,192	1,150	1,005	8
Ethylene	1,231	839	642	651	47
Pesticides	202	157	223	211	28
Pharmaceuticals	194	154	107	58	26
Rubber tires[b]	29,276	24,478	19,932	18,527	20

a Nutrient content. **b** In thousands of units, not including wheelbarrow and bicycle tires. **na** = not available. **Sources:** State Statistical Bureau of the People's Republic of China, *China Daily*, *China Economic News*, Central Intelligence Agency

CHEMICAL IMPORTS: Big increases last year

$ Millions[a]	1988	1987	1986	Change 1987-88
Organic chemicals	$1701	$ 998	$ 781	71%
Inorganic chemicals	448	422	330	6
Dyeing, tanning, coloring materials	237	202	158	17
Medicinal and pharmaceutical products	384	229	149	67
Fertilizers[b]	2335	1399	678	67
Plastic materials, resins, cellulose esters and ethers	3558	1470	1216	142
TOTAL	**$9139**	**$5008**	**$3533**	**82%**

a Includes cost, insurance, and freight. **b** Manufactured. **Source:** General Administration of Customs of the People's Republic of China

CHEMICAL EXPORTS: Expansion continues

$ Millions[a]	1988	1987	1986	Change 1987-88
Organic chemicals	$ 575	$ 500	$ 386	15%
Inorganic chemicals	762	553	357	38
Dyeing, tanning, coloring materials	229	175	117	31
Medicinal and pharmaceutical products	468	408	317	15
Essential oils, perfumes, cleansing materials	183	136	102	34
Explosives, pyrotechnic products	298	183	144	63
TOTAL	**$2897**	**$2235**	**$1629**	**30%**

a Free on board. **Source:** General Administration of Customs of the People's Republic of China

TAIWAN

INDUSTRY TRENDS: Chemical growth slows

Industrial production indexes, 1981 = 100	1988	1987	1986	1985	Change 1987-88
All manufacturing	182.6	175.3	155.0	133.5	4%
Chemical materials	191.6	188.1	179.0	149.0	2
Basic chemicals	135.0	140.5	143.7	125.7	−4
Petrochemicals	164.8	167.4	170.6	154.7	−2
Fertilizers	90.8	83.7	85.8	65.6	8
Synthetic fibers	215.8	207.8	185.2	146.7	4
Plastics and resins	240.1	230.0	212.3	164.6	4
Chemical products	219.4	197.3	178.2	153.7	11

Source: Taiwan Ministry of Economic Affairs

FOREIGN TRADE: Chemical imports up 35%

$ Millions	1988	1987	1986	1985
Exports[a]	$60,587	$53,339	$39,786	$30,717
Imports[b]	49,650	34,502	24,175	20,107
Trade balance	10,937	18,837	15,611	10,610
Chemical exports[a,c]	2,448	1,760	1,487	1,340
Chemical imports[b,c]	7,231	5,341	4,163	2,967
Chemical trade balance	−4,783	−3,581	−2,676	−1,627

Note: Statistics converted from NT$ to U.S. dollars on basis of $1.00 equals: 1988, NT$28.6; 1987, NT$31.8; 1986, NT$37.9; 1985, NT$39.8. **a** Free on board. **b** Includes cost, insurance, and freight. **c** Includes chemicals and chemical products, but not plastic and rubber products. **Sources:** Taiwan Council for Economic Planning & Development, C&EN estimates

PRODUCTION: Mixed results for 1988

Thousands of metric tons, unless otherwise noted	1988	1987	1986	1985	Change 1987-88
Man-made fibers	1586	1529	1359	1112	4%
Sulfuric acid	756	742	815	733	2
Polyvinyl chloride	807	832	795	633	−3
Vinyl chloride	725	710	668	511	2
Ammonium sulfate	485	485	604	507	0
Ammonia, anhydrous	338	296	323	252	14
Sodium hydroxide	333	378	366	387	−12
Compound fertilizer	361	335	302	249	8
Hydrochloric acid	257	265	256	228	−3
Urea	306	244	214	139	25
Calcium superphosphate	212	259	248	132	−18
Ethylene glycol	208	202	222	199	3
Oxygen[a]	450	505	506	347	−11
Polyethylene[b]	395	384	398	350	3
Paints	247	229	184	130	8
Dioctyl lactam	178	205	196	142	−13
Styrene	331	310	243	234	7
Acrylonitrile	144	125	150	137	15
Acrylonitrile-butadiene-styrene	234	162	119	52	44

a Millions of cubic meters. **b** High and low density. **Sources:** Taiwan Council for Economic Planning & Development

ACS Committee on Professional Training 1988 Annual Report

Summary of data from approved schools, 1984–88

	Bachelors				Masters		Doctorates	
	Number of schools	Graduates (totals)	Certified graduates	Noncertified graduates	Number of schools	Graduates	Number of schools	Graduates
CHEMISTRY								
1984	577	9819	4201	5618	321	1637	189	1777
1985	579	9679	4021	5658	316	1621	186	1806
1986	580	9295	3892	5403	315	1620	187	1885
1987	582	8848	3663	5185	316	1636	188	1936
1988	584	8271	3428	4843	319	1584	192	1955
CHEMICAL ENGINEERING[a]								
1984	120	6866	6866	—	114	1436	101	357
1985	123	6442	6442	—	118	1489	104	418
1986	118	5229	5229	—	116	1244	103	460
1987	107	4435	4435	—	103	1078	90	533
1988	128	3577	3577	—	124	1049	106	617

[a] Chemical engineering departments are not required to report their data to CPT, so the number of departments included in this category varies from year to year

The number of bachelor's degree graduates in chemistry from colleges and universities whose undergraduate chemistry programs are approved by the American Chemical Society decreased 6.8% in the 1987–88 academic year from the previous year. The number of master's degrees from these departments decreased 3.3%, and the number of Ph.D. degrees continued to rise for the ninth year in a row, this year less than 1%. These departments project that in 1989 the number of degrees will increase at all three levels—bachelors 5.9%, masters 15.2%, and Ph.D.s 15%. (It should be noted, however, that these projections are usually higher than actual counts a year later.)

The percentage of baccalaureate graduates certified to ACS was a little over 41%, about the same as last year. (Certified graduates are those who have completed the curriculum specified by the Committee on Professional Training and are eligible for full membership in ACS; noncertified graduates may become associate members of ACS upon graduation and full members after three years of professional experience or a higher degree in a chemical science.)

Of the total of 8271 bachelor's degree graduates from the approved schools, 2074 were reported as planning to go to graduate school, and 1739 to professional schools.

A tabulation of the numbers of bachelor's degrees (certified and noncertified), master's degrees, and Ph.D. degrees awarded in 1987–88 by institutions whose chemistry programs are ACS-approved may be found at the end of this report. The data are summarized in the two smaller tables. These tables also include numbers of chemical engineering graduates from institutions whose programs are accredited by the American Institute of Chemical Engineers and the Accreditation Board for Engineering & Technology. (Note: These departments are not required to report their data to CPT, so the number of departments included varies each year.) Included for the fifth year is a table with information on graduate student enrollments in chemistry departments whose undergraduate programs are ACS-approved.

The number of bachelor's degrees in chemical engineering from the 128 AIChE-ABET-accredited departments that reported in 1988 decreased 24% from the total reported by 107 departments in 1987, the fifth decrease in a row. These 128 departments reported an expected increase in bachelor's degrees of 1.5% in 1989. At the graduate level, the number of chemical engineering master's degrees decreased for the third year, and the number of Ph.D. degrees increased for the ninth year in a row. The number of master's degrees was down 28% from 1987, and the number of Ph.D.s was up 13.6%. Projected 1989 numbers of degrees in chemical engineering from these schools are up 9% for master's degrees and up 17% for Ph.D.s.

The chemistry programs at ACS-approved schools normally are reevaluated at five-year intervals. There were 590 colleges and universities on the approved list at the end

Summary of totals from 1988 reports from approved schools

	Schools reporting	Men	Women	Total
CHEMISTRY				
Bachelors, Total	584	5033	3238	8271
Certified		2102	1326	3428
Noncertified		2931	1912	4843
Masters	319	1054	530	1584
Doctorates	192	1504	451	1955
CHEMICAL ENGINEERING				
Bachelors, Certified	128	2653	924	3577
Masters	124	861	188	1049
Doctorates	106	538	79	617

Graduate student enrollments in departments whose undergraduate chemistry programs are ACS approved

	Number of departments	First-year graduate students		All graduate students	
		Full time	Part time	Full time	Part time
M.S. departments					
Fall 1984	131	468	270	1099	990
Fall 1985	129	417	292	1106	962
Fall 1986	128	474	264	1190	1051
Fall 1987	127	406	315	1136	993
Ph.D. departments					
Fall 1984	186	3404	227	14,194	1314
Fall 1985	187	3455	208	14,379	1372
Fall 1986	187	3475	235	14,438	1355
Fall 1987	192	3441	201	15,212	1231

a Departments whose highest offering is the master's degree in chemistry

of 1988. During the year the committee studied the chemistry programs of 227 of the approved schools and of 23 schools applying for ACS approval. Each evaluation involved a review of extensive documentary materials submitted by the department chairman describing the current status of the program.

Committee members, 1988

Alice J. Cunningham, *chairman*
Agnes Scott College
Henry A. Bent
North Carolina State University
Norman C. Craig
Oberlin College
Marjorie C. Caserio
University of California, Irvine
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Ethicon Inc.
Richard P. Van Duyne
Northwestern University
Barbara A. Gallagher,
committee secretary
Cathy A. Nelson, *staff associate*
Dolphine S. Hite, *program assistant*
American Chemical Society

Six schools were added to the ACS-approved list by the ACS Committee on Professional Training in 1988; five were put on probation; one was removed from probation; two continued on probation; and none was removed from the list.

In 1988 the committee approved an Extension of the Guidelines for Undergraduate Professional Education in Chemistry. The 1988 extension pertains to curriculum options for certifiable degrees in chemistry with an emphasis in biochemistry, polymer chemistry, and/or chemistry education. One of the most important goals in developing the 1988 extension was to emphasize the flexibility in curricular organization for certifiable degrees. An approved department may choose to expand its certifiable degree options to include those described in the 1988 extension, but there is no obligation to do so. Two biochemistry applications were approved. Departments may obtain application forms for the options from the Office of Professional Training at ACS headquarters. Other options under consideration include materials chemistry and chemical physics.

The committee voted to enhance the usefulness of the ACS Directory of Graduate Research by including departmental telecopier, or fax, numbers and individual computer addresses in the 1989 edition. Plans were also approved to include departmental and biographical information from the directory in the ACS electronic communications network (ACS/ECOM). This service will be accessible through Telenet phone numbers and be available to ACS members and nonmembers.

The survey of construction projects at ACS-approved schools was continued in 1988. Schools indicated the phase of their construction (planning, in progress, completed in the last four years, or no construction) and the mode by which they would be willing to share information about their project (by phone, letter, or site visit). A complete listing of the results or a custom search by construction stage, communication medium, and geographic location can be obtained from the Office of Professional Training at ACS headquarters.

Other CPT activities in 1988 included preparation of an advisory statement to the National Science Foundation supporting the NSF initiative on the chemistry curriculum; endorsement of an Association of American Colleges project to produce a monograph on various undergraduate majors; participation in discussions of the ACS Agenda Relative to Long-Range Science Policy Issues; representation on the Committee on Professional Relations Task Force on Academic Guidelines; a presentation to the International Society for Optical Engineering; and interaction with the ACS Society Committee on Education Task Force on ACS Involvement in the Two-Year Colleges.

The committee would like to acknowledge and thank the following visiting associates of the committee who conducted on-site visits to schools on the approved list or applying for ACS approval during 1988: Martin N. Ackermann, Oberlin College; Ronald D. Archer, University of Massachusetts; Eugene C. Ashby, Georgia Institute of Technology; J. Nicholas Burnett, Davidson College; Roger L. DeKock, Calvin College; Robert W. Gleason, Middlebury College; Ronald C. Johnson, Emory University; William Jones, University of Florida; Royston M. Roberts, University of Texas; Robert I. Walter, University of Illinois, Chicago; Thomas Wartik, Pennsylvania State University; and Gene G. Wubbels, Grinnell College. □

Chemistry and chemical engineering degrees awarded by ACS-approved schools, 1987–88

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Abilene Christian U	8	6	2	—			
Adelphi U	1	4	3	—			
Agnes Scott C	4	0	—	—			
Akron, U of	29	5	6	6	a		
Alabama, U of							
Birmingham	5	2	1	0			
Huntsville	1	6	2	—	a		
Tuscaloosa	3	11	2	2	30	4	1
Alaska, U of	5	1	2	—			
Albion C	1	8	—	—			
Albright C	2	12	—	—			
Alfred U	5	0	—	—			
Allegheny C	6	15	—	—			
Alma C	2	7	—	—			
American U	1	1	1	5			
Amherst C	1	11	—	—			
Andrews U	7	10	—	—			
Appalachian State U	5	4	0	—			
Arizona State U	14	14	1	11	21	7	2
Arizona, U of	10	49	6	19	21	4	0
Arkansas, U of							
Fayetteville	2	8	3	8	32	12	6
Little Rock	4	5	1	—			
Ashland C	0	4	—	—			
Auburn U	9	21	6	1	25	18	4
Augsburg C	2	8	—	—			
Augustana C							
Illinois	1	5	—	—			
South Dakota	0	9	—	—			
Austin C	2	7	—	—			
Baldwin-Wallace C	2	6	—	—			
Ball State U	8	5	9	—			
Barnard C	2	11	—	—			
Bates C	2	13	—	—			
Baylor U	5	15	1	1			
Beloit C	2	7	—	—			
Bemidji State U	7	6	—	—			
Birmingham Southern C	2	7	—	—			
Bloomsburg U	2	7	—	—			
Boston C	19	0	3	2			
Boston U	10	10	1	2			
Bowdoin C	1	32	—	—			
Bowling Green State U	5	10	13	0			
Bradley U	2	10	1	—			
Brandeis U	0	14	6	10			
Bridgeport, U of	1	0	2	—			
Bridgewater State C	3	6	0	—			
Brigham Young U	18	20	4	7	31	9	5
Brown U	0	12	4	16	2	0	1
Bryn Mawr C	21	0	0	3			
Bucknell U	6	16	3	—	17	4	—
Butler U	4	8	5	—			
California Institute of Tech	7	0	3	34	4	4	17
California Polytechnic State U	20	34	4	—			
California State Polytechnic U	2	7	4	—	a		
California State U							
Bakersfield	3	5	—	—			
Chico	0	20	—	—			
Dominguez Hill	2	2	—	—			
Fresno	7	7	4	—			
Fullerton	0	20	5	—			
Hayward	10	11	3	—			
Long Beach	23	22	14	—	a		
Los Angeles	9	3	4	—			
Northridge	4	20	3	—			
Sacramento	7	14	2	—			
San Bernardino	0	1	—	—			
Stanislaus	4	2	—	—			
California, U of							
Berkeley	67	1	6	75	72	15	32
Davis	23	8	5	11	30	8	3
Irvine	12	49	1	13			
Los Angeles	5	73	5	33	21	19	1
Riverside	8	0	8	13			
San Diego	29	0	32	27	a		
Santa Barbara	9	15	8	12	22	6	5
Santa Cruz	22	0	6	11			
Calvin C	4	14	—	—			
Canisius C	9	6	—	—			
Capital U	2	7	—	—			
Carleton C	1	24	—	—			
Carnegie Mellon U	20	1	1	10	37	7	11
Carroll C	0	3	—	—			
Carthage C	2	2	—	—			
Case Western Reserve U	7	42	10	9	24	11	1
Catholic U of America	0	4	3	1	a		
Centenary C of Louisiana	0	1	—	—			
Central C	0	9	—	—			
Central Connecticut State U	4	8	0	—			
Central Florida, U of	6	0	2	—			
Central Michigan U	1	10	3	—			
Central State U							
Ohio	0	0	—	—			
Oklahoma	0	4	—	—			
Centrel C	2	5	—	—			
Charleston, C of	5	4	—	—			
Chatham C	4	0	—	—			
Chestnut Hill C	4	3	—	—			
Chicago, U of	3	25	11	26			
Christian Brothers C[b]					a		
Cincinnati, U of	17	0	15	21	62	6	5
Citadel, The	2	2	—	—			
City U of New York							
Graduate Center	—	—	0	8			
Brooklyn C	1	28	5	—			
City C	3	5	7	—	a		
Herbert H. Lehman C	9	1	—	—			
Hunter C	1	9	0	0			
Queens C	1	17	10	3			
Clarion U	4	2	—	—			
Clark U	12	3	2	2			
Clarkson U	6	4	4	3	44	18	7
Clemson U	6	3	7	11	27	5	2
Cleveland State U	21	2	6	1	13	3	1
Coe C	1	4	—	—			
Colby C	3	5	—	—			
Colgate U	8	3	—	—			
Colorado C	8	1	—	—			
Colorado School of Mines	11	0	5	4	59	14	2
Colorado State U	9	13	3	14	14	13	1
Colorado, U of							
Boulder	7	37	10	24	45	10	7
Colorado Springs	4	1	—	—			
Denver	6	4	8	—			
Columbia U	4	11	17	10	20	17	7
Concordia C	5	7	—	—			
Connecticut, U of	12	12	17	5	25	7	5
Cooper Union[b]					a		
Cornell C	0	10	—	—			
Cornell U	27	27	28	20	33	5	8
Creighton U	3	14	—	—			
Dartmouth C	0	19	1	6			
David Lipscomb C	0	10	—	—			
Davidson C	3	6	—	—			
Dayton, U of	7	9	—	—	18	6	—
DePaul U	3	2	8	—			
DePauw U	2	9	—	—			
Delaware State C	9	0	5	—			
Delaware Valley C of Science & Agriculture	9	0	—	—			
Delaware, U of	22	12	9	12	35	1	13
Delta State U	1	12	—	—			
Denison U	2	9	—	—			
Denver, U of	1	8	6	2			
Detroit, U of	6	1	7	1	a		
Dickinson C	1	6	—	—			
Drake U	5	1	—	—			
Drew U	0	2	—	—			
Drexel U	6	0	9	4	59	9	3
Duke U	10	33	2	18			
Duquesne U	3	9	1	0			
Earlham C	0	5	—	—			
East Carolina U	3	4	2	—			

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
East Stroudsburg U	5	3	0	—			
East Tennessee State U	7	4	2	—			
East Texas State U	1	2	4	—			
Eastern Illinois U	13	2	5	—			
Eastern Kentucky U	6	21	1	—			
Eastern Michigan U	12	13	2	—			
Eastern New Mexico U	1	1	3	—			
Eckerd C	1	2	—	—			
Elizabethtown C	0	7	—	—			
Elmhurst C	1	14	—	—			
Emory U	4	39	9	8			
Emporia State U	5	5	2	—			
Evansville, U of	6	5	—	—			
Fairfield U	5	0	—	—			
Fairleigh Dickinson U							
Madison	6	0	2	—			
Teaneck	6	3	2	—			
Fisk U	5	1	2	—			
Florida Atlantic U	3	10	0	—			
Florida Institute of Tech	0	5	3	—	9	4	—
Florida International U	6	15	0	—			
Florida State U	1	22	5	5			
Florida, U of	4	34	9	28	27	4	12
Fordham U	0	15	2	—			
Fort Lewis C	4	6	—	—			
Franklin & Marshall C	7	2	—	—			
Furman U	10	9	1	—			
Geneva C	0	9	—	—			
George Mason U	6	3	—	—			
George Washington U	3	7	0	0			
Georgetown U	13	0	4	13			
Georgia Institute of Tech	14	0	6	16	72	9	14
Georgia State U	4	7	5	—			
Georgia, U of	4	11	2	7			
Gettysburg C	8	5	—	—			
Glassboro State C	3	2	—	—			
Gonzaga U	4	1	—	—			
Goucher C	1	1	—	—			
Grand Valley State C	0	8	—	—			
Grinnell C	3	15	—	—			
Gustavus Adolphus C	5	14	—	—			
Hamilton C	0	2	—	—			
Hamline U	5	5	—	—			
Hampden-Sydney C	4	3	—	—			
Hampton U	6	0	1	—			
Hartford, U of	1	5	0	—			
Hartwick C	0	2	—	—			
Harvard U	14	0	19	24			
Harvey Mudd C	15	0	—	—			
Haverford C	18	1	—	—			
Hawaii, U of, Manoa	10	3	2	1			
Hiram C	5	4	—	—			
Hobart & William Smith C	1	8	—	—			
Hofstra U	2	8	—	—			
Hollins C	0	1	—	—			
Holy Cross, C of the	10	16	—	—			
Hope C	10	13	—	—			
Houston, U of	12	0	9	8	25	36	6
Howard U	0	13	1	3	14	4	—
Humboldt State U	4	3	—	—			
Idaho State U	3	7	0	—			
Idaho, U of	3	8	5	6	17	8	3
Illinois Benedictine C	11	0	—	—			
Illinois Institute of Tech	8	0	7	0	[a]		
Illinois State U	30	6	9	—			
Illinois Wesleyan U	6	3	—	—			
Illinois, U of							
Chicago	15	7	17	11	24	6	5
Urbana-Champaign	59	71	22	43	69	18	17
Indiana State U	9	0	1	—			
Indiana U–Purdue U							
Fort Wayne	0	5	—	—			
Indianapolis	1	24	7	—			
Indiana U	24	124	10	27			
Indiana U Northwest	1	6	—	—			
Indiana U, South Bend	3	0	—	—			
Indiana U of Pennsylvania	8	8	1	—			
Interamerican U of Puerto Rico	2	5	—	—			
Iowa State U	12	7	10	36	57	8	9
Iowa, U of	20	4	8	8	19	7	4
Ithaca C	6	1	—	—			
Jackson State U	2	1	0	—			
James Madison U	4	11	—	—			
John Carroll C	2	5	1	—			
Johns Hopkins U	16	0	10	9	11	5	4
Juniata C	5	8	—	—			
Kalamazoo C	2	13	—	—			
Kansas State U	6	3	2	11	23	4	3
Kansas, U of	8	12	0	1	24	5	1
Kean C of New Jersey	4	8	—	—			
Kearney State C	0	7	—	—			
Kent State U	10	8	0	3			
Kentucky, U of	4	15	4	7	27	12	3
Kenyon C	3	9	—	—			
King's C	2	7	—	—			
Knox C	1	18	—	—			
La Salle U	3	1	—	—			
Lafayette C	6	7	—	—	11	—	—
Lake Forest C	1	5	—	—			
Lamar U	8	4	4	—	14	3	4
Lawrence Institute of Tech	8	0	—	—			
Lawrence U[c]	2	2	6	3			
LeMoyne C	6	2	—	—			
Lebanon Valley C	7	2	—	—			
Lehigh U	5	8	15	6	24	19	14
Lewis & Clark C	1	3	—	—			
Lincoln U	0	5	—	—			
Long Island U							
Brooklyn Campus	2	1	6	—			
C.W. Post Center	0	0	—	—			
Loras C	1	9	—	—			
Louisiana State U							
Baton Rouge	5	7	2	13	20	12	5
Shreveport	5	0	—	—			
Louisiana Technological U	2	3	3	—	16	4	2
Louisville, U of	12	11	1	4	10	4	1
Lowell, U of	4	4	9	8	19	5	—
Loyola C	0	3	—	—			
Loyola Marymount U	5	0	—	—			
Loyola U							
Chicago	9	16	5	2			
New Orleans	1	4	—	—			
Luther C	1	12	—	—			
Macalester C	2	3	—	—			
Maine, U of, Orono	1	2	1	1	26	3	0
Manhattan C[d]	5	9	—	—	12	10	—
Manhattanville C	2	0	—	—			
Mankato State U	2	9	0	—			
Marietta C	3	1	—	—			
Marist C	1	1	—	—			
Marquette U	17	0	4	4			
Marshall U	4	16	2	—			
Maryland, U of							
College Park	16	47	15	26	33	1	0
Baltimore County	10	32	0	0			
Massachusetts Institute of Tech	24	0	4	40	48	41	26
Massachusetts, U of	13	9	8	13	24	3	7
McNeese State U	2	1	2	—			
Memphis State U	2	6	1	1			
Mercer U	1	6	—	—			
Merrimack C	9	0	—	—			
Metropolitan State C	6	12	—	—			
Miami U	14	35	5	6			
Miami, U of	2	35	2	8			
Michigan State U	25	10	4	24	20	8	7
Michigan Technological U	8	0	5	0	40	5	0
Michigan, U of							
Ann Arbor	47	0	19	14	51	17	9
Dearborn	15	10	—	—			
Flint	4	2	—	—			
Middle Tennessee State U	0	16	6	—			
Middlebury C	0	4	0	—			
Midwestern State U	4	4	—	—			
Millersville U	1	9	—	—			
Millsaps C	1	14	—	—			
Minnesota, U of							
Duluth	14	9	5	—			
Minneapolis	43	0	7	30	91	12	20
Mississippi C	2	4	—	—			
Mississippi State U	1	12	1	3	30	0	—

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Mississippi, U of	4	3	3	3	13	5	1
Missouri Western State C	2	0	—	—			
Missouri, U of							
Columbia	13	5	4	7	27	4	4
Kansas City	9	12	3	1			
Rolla	10	0	4	4	60	6	8
St. Louis	6	9	4	7			
Monmouth C	5	0	—	—			
Montana C of Mineral Science & Technology	2	1	0	—			
Montana State U	1	6	5	7	29	7	0
Montana, U of	7	4	5	3			
Montclair State C	7	12	4	—			
Moorhead State U	3	1	—	—			
Moravian C	0	3	—	—			
Morehouse C[e]	2	3	5	2			
Morgan State U	1	4	—	—			
Mount Holyoke C	0	7	0	0			
Mount Saint Vincent, C of[d]	0	1	—	—			
Muhlenberg C	0	9	—	—			
Murray State U	8	13	4	—			
Muskingum C	2	3	—	—			
Nebraska Wesleyan U	1	2	—	—			
Nebraska, U of							
Lincoln	0	8	4	15	36	6	1
Omaha	9	4	—	—			
Nevada, U of							
Las Vegas	1	5	0	—			
Reno	3	2	5	3			
New Hampshire, U of	6	4	2	6	19	6	1
New Jersey Institute of Tech[b]					43	13	2
New Mexico Highlands U	0	3	0	—			
New Mexico Institute of Mining & Tech	11	0	5	1			
New Mexico State U	0	19	4	7	23	3	0
New Mexico, U of	6	14	6	6	8	6	1
New Orleans, U of	6	7	0	4			
New York U	6	38	15	9			
Niagara U	0	5	—	—			
North Alabama, U of	7	11	—	—			
North Carolina A&T State U	2	0	1	—			
North Carolina Central U	1	6	2	—			
North Carolina State U	21	35	3	5	78	6	7
North Carolina, U of							
Asheville	2	1	—	—			
Chapel Hill	30	72	10	43			
Charlotte	2	5	1	—			
Greensboro	4	4	3	—			
Wilmington	5	13	—	—			
North Dakota State U	0	16	6	5			
North Dakota, U of	2	5	2	9	15	1	—
North Texas, U of	4	4	10	3			
Northeast Louisiana U	1	4	2	—			
Northeast Missouri State U	2	10	—	—			
Northeastern Illinois U	1	3	4	—			
Northeastern U	3	0	4	12	a		
Northern Arizona U	7	16	3	—			
Northern Colorado, U of	5	0	0	0			
Northern Illinois U	8	16	3	7			
Northern Iowa, U of	7	10	1	—			
Northern Kentucky U	2	8	—	—			
Northern Michigan U	0	3	0	—			
Northwest Missouri State U	3	1	—	—			
Northwestern State U of Louisiana	1	0	—	—			
Northwestern U	7	8	22	22	30	1	16
Notre Dame, U of	8	8	6	11	29	7	7
Oakland U	3	4	0	—			
Oberlin C	0	18	—	—			
Occidental C	1	14	—	—			
Ohio Northern U	4	4	—	—			
Ohio State U	33	0	0	38	40	15	6
Ohio U	5	6	2	7	15	5	1
Ohio Wesleyan U	1	4	—	—			
Oklahoma State U	0	2	2	7	22	14	7
Oklahoma, U of	11	19	12	4	21	23	6
Old Dominion U	5	1	7	—			
Oregon State U	13	0	4	14	24	11	3
Oregon, U of	5	25	5	11			
Pace U							
New York Campus	2	3	—	—			
Pleasantville Campus	3	4	—	—			
Pacific Lutheran U	3	8	—	—			
Pacific, U of the	4	3	0	0			
Pennsylvania State U	7	21	7	21	73	14	8
Pennsylvania, U of	4	16	5	19	25	5	15
Philadelphia C of Pharmacy & Science	1	0	1	1			
Philadelphia C of Textiles & Science	2	0	—	—			
Pittsburgh State U	4	1	2	—			
Pittsburgh, U of	14	38	14	15	41	17	6
Polytechnic U	3	0	14	7	11	15	6
Pomona C	6	7	—	—			
Portland State U	1	9	1	0			
Pratt Institute[b]					3	—	—
Princeton U	8	5	15	26	12	3	13
Providence C	2	9	0	0			
Puerto Rico, U of							
Mayaguez	9	2	4	—	55	2	—
Rio Piedras	6	23	8	4			
Puget Sound, U of	2	0	—	—			
Purdue U	21	18	13	35	73	14	12
Purdue U Calumet	7	3	—	—			
Ramapo C of New Jersey	1	3	—	—			
Randolph Macon C	0	3	—	—			
Randolph-Macon Woman's C	2	2	—	—			
Redlands, U of	1	3	—	—			
Reed C	7	1	—	—			
Rensselaer Polytechnic Institute	19	0	10	16	41	11	13
Rhode Island C	1	7	—	—			
Rhode Island, U of	7	3	2	6	16	6	1
Rhodes C	4	10	—	—			
Rice U	2	4	11	12	8	6	7
Richmond, U of	1	8	—	—			
Rider C	5	0	—	—			
Ripon C	1	3	—	—			
Roanoke C	2	1	—	—			
Rochester Institute of Tech	2	9	3	—			
Rochester, U of	9	3	32	16	22	13	4
Rollins C	2	0	—	—			
Roosevelt U	8	0	4	—			
Rose-Hulman Institute of Tech	4	0	—	—	31	3	—
Russell Sage C	2	1	—	—			
Rutgers U							
Camden C	0	12	—	—			
New Brunswick	20	33	13	14	27	29	8
Newark C of Arts & Sciences	9	4	9	2			
Saginaw Valley State C	2	9	—	—			
St. Anselm C	0	9	—	—			
St. Catherine, C of	3	5	—	—			
St. Cloud State U	4	9	—	—			
St. John Fisher C	2	5	—	—			
St. John's U/C of St. Benedict	4	6	—	—			
St. John's U	11	0	2	—			
St. Joseph C	4	2	4	—			
St. Joseph's U	5	13	6	—			
St. Lawrence U	3	8	—	—			
St. Louis U	2	32	5	—			
St. Mary's C	3	3	—	—			
St. Michael's C	2	0	—	—			
St. Olaf C	8	43	—	—			
St. Peter's C	2	2	—	—			
St. Thomas, C of	4	8	—	—			
Salem State C	2	0	—	—			
Sam Houston State U	5	1	3	—			
San Diego State U	14	0	9	0			
San Francisco State U	6	24	9	—			
San Francisco, U of	1	6	4	—			
San Jose State U	21	6	9	—	a		
Sangamon State U	1	0	—	—			
Santa Clara U	4	5	—	—			
Scranton, U of	2	11	12	—			
Seattle U	0	4	—	—			
Seton Hall U	3	9	9	4			
Shippensburg U	6	6	2	—			
Siena C	9	0	—	—			
Simmons C	0	0	—	—			
Skidmore C	1	16	—	—			
Smith C	2	3	0	0			
Sonoma State U	4	9	—	—			
South Alabama, U of[b]					20	1	—

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
South Carolina, U of	2	20	5	29	28	7	1
South Dakota School of Mines & Tech	5	0	1	—	25	2	—
South Dakota State U	1	29	6	—			
South Dakota, U of	8	13	2	—			
South Florida, U of	22	27	3	2	22	6	1
Southeast Missouri State U	0	8	—	—			
Southeastern Louisiana U	4	0	—	—			
Southeastern Massachusetts U	6	5	3	—			
Southern California, U of	16	2	1	11	16	6	3
Southern Colorado, U of	0	5	0	—			
Southern Illinois U							
Carbondale	12	1	5	8			
Edwardsville	19	5	6	—			
Southern Methodist U	6	7	1	—			
Southern Mississippi, U of	1	14	4	1			
Southern Oregon State C	2	2	—	—			
Southern U and A&M C	3	2	5	—			
Southwest Missouri State U	8	14	—	—			
Southwest State U	1	1	—	—			
Southwest Texas State U	10	3	3	—			
Southwestern Louisiana, U of	0	17	1	—	13	6	—
Southwestern Oklahoma State U	6	5	—	—			
Stanford U	6	6	4	31	12	17	12
State U of New York							
Albany	10	11	8	7			
Binghamton	5	14	6	5			
Buffalo	19	9	4	15	31	15	11
Stony Brook	10	29	5	14			
C of Brockport	3	6	—	—			
C at Buffalo	9	11	3	—			
C at Cortland	7	4	—	—			
C at Fredonia	6	4	1	—			
C at Geneseo	9	4	—	—			
C at New Paltz	8	1	4	—			
C at Oneonta	1	10	0	—			
C at Oswego	9	2	2	—			
C at Plattsburgh	5	14	3	—			
C at Potsdam	0	8	—	—			
Stephen F. Austin State U	6	0	0	—			
Stetson U	3	2	—	—			
Stevens Institute of Tech	3	2	4	3	8	8	2
Stockton State C	2	15	—	—			
Suffolk U	1	1	—	—			
Susquehanna U	1	3	—	—			
Swarthmore C	6	5	—	—			
Syracuse U	8	5	0	11	9	5	3
Temple U	19	0	3	4			
Tennessee Technological U	2	5	3	—	18	4	0
Tennessee, U of							
Chattanooga	9	14	—	—			
Knoxville	2	8	6	18	36	13	3
Martin	3	6	—	—			
Texas A&I U	2	0	3	—	18	7	0
Texas A&M U	8	14	16	29	69	10	7
Texas Christian U	3	10	1	7			
Texas Southern U	9	0	4	—			
Texas Tech U	2	5	3	8	5	10	1
Texas Woman's U	0	4	4	0			
Texas, U							
Arlington	9	13	2	4			
Austin	49	0	11	17	41	15	18
Dallas	7	1	5	1			
El Paso	10	1	12	—			
Thiel C	0	5	—	—			
Thomas More C	3	0	—	—			
Toledo, U of	3	9	2	2	20	4	0
Towson State U	2	12	—	—			
Trenton State C	14	0	—	—			
Trinity C	11	6	1	—			
Trinity U	5	6	—	—			
Tri-State U[b]					15	—	—
Tufts U	1	10	1	6	14	11	1
Tulane U of Louisiana	2	7	0	1	8	3	1
Tulsa, U of	5	0	—	—	a		
Tuskegee U	0	3	3	—	5	—	—
Union C	4	10	—	—			
U.S. Air Force Academy	12	2	—	—			
U.S. Naval Academy	14	6	—	—			
Ursinus C	4	10	—	—			
Utah State U	8	0	1	4			
Utah, U of	3	16	9	25	29	2	5
Valparaiso U	3	32	—	—			
Vanderbilt U	0	10	4	4	20	3	1
Vassar C	0	5	0	—			
Vermont, U of	16	0	1	10			
Villanova U	10	0	8	1	12	4	—
Virginia Commonwealth U	4	15	3	6			
Virginia Military Institute	4	0	—	—			
Virginia Polytechnic Institute & State U	15	19	8	13	44	9	5
Virginia, U of	11	52	15	14	25	18	7
Wabash C	7	11	—	—			
Wagner C	1	2	—	—			
Wake Forest U	0	32	3	1			
Washburn U of Topeka	4	2	—	—			
Washington C	1	0	—	—			
Washington State U	4	6	7	4	23	7	3
Washington U	2	6	12	9	26	15	4
Washington & Jefferson C	1	23	—	—			
Washington & Lee U	1	12	—	—			
Washington, U of	16	29	14	21	67	6	4
Wayne State U	37	13	17	22	28	13	2
Waynesburg C	0	0	—	—			
Weber State C	4	2	—	—			
Wellesley C	13	24	—	—			
Wesleyan U	0	7	0	2			
West Chester U	3	13	5	—			
West Florida, U of	4	5	—	—			
West Texas State U	0	9	1	—			
West Virginia Institute of Tech[b]					11	0	—
West Virginia State C	3	6	—	—			
West Virginia U	14	28	4	4	21	6	2
Western Illinois U	1	8	2	—			
Western Kentucky U	0	10	2	—			
Western Maryland C	2	3	—	—			
Western Michigan U	1	14	4	2			
Western New England C	0	0	—	—			
Western Washington U	11	11	2	—			
Westminster C	1	2	—	—			
Wheaton C							
Illinois	3	10	—	—			
Massachusetts	2	2	—	—			
Wheeling Jesuit C	1	8	—	—			
Whitman C	3	2	—	—			
Whittier C	2	7	—	—			
Wichita State U	6	8	3	0			
Widener U	3	2	—	—	7	2	—
Wilkes C	2	1	—	—			
Willamette U	1	11	—	—			
William Paterson C of N.J.	0	3	—	—			
William & Mary, C of	24	8	4	—			
Williams C	5	31	—	—			
Winona State U	2	2	—	—			
Wisconsin, U of							
Eau Claire	10	11	—	—			
Green Bay	0	6	—	—			
La Crosse	0	13	—	—			
Madison	38	0	13	41	68	10	18
Milwaukee	0	13	6	8			
Oshkosh	8	0	—	—			
Parkside	6	2	—	—			
Platteville	0	3	—	—			
River Falls	11	7	—	—			
Stevens Point	7	15	—	—			
Superior	2	2	—	—			
Wittenberg U	4	8	—	—			
Wooster, C of	3	29	—	—			
Worcester Polytechnic Institute	12	5	1	0	34	2	5
Wright State U	20	9	13	—			
Wyoming, U of	8	0	4	5	7	3	4
Xavier U	5	6	—	—			
Xavier U of Louisiana	2	39	—	—			
Yale U	0	15	15	22	2	3	3
Youngstown State U	8	44	5	—	a		
TOTALS	**3428**	**4843**	**1584**	**1955**	**3577**	**1049**	**617**

NOTE: For brevity, "B.S." and "M.S." are used to denote all bachelor's and master's degrees, respectively, in each column. **a** Data not submitted. **b** Listed on basis of accreditation by AIChE-ABET. **c** Master's and Ph.D. degrees given by the Institute of Paper Chemistry. **d** The chemistry programs at Mount Saint Vincent and Manhattan College are integrated into a combined department with all instruction in chemistry located at Manhattan College. **●** Master's and Ph.D. degrees given by Atlanta University.

Berkeley, Illinois top producers of chemists

The University of California, Berkeley, was the dominant producer of new Ph.D. chemists in the 1987-88 academic year, with 75. The University of Illinois, Urbana-Champaign, and University of North Carolina, Chapel Hill, shared the second spot with 43 each.

This was the fourth year in a row and the seventh time in the past 15 years that Berkeley has topped the Ph.D. list. In the other years the honor went to Urbana-Champaign.

These are but some of the facts that can be extracted from the statistical data contained in the latest annual report of ACS's Committee on Professional Training (CPT) (see page 93). The report includes the number of new doctoral, master's, and bachelor's degree graduates from all chemistry departments with CPT-approved bachelor programs.

Indiana University was the largest producer of bachelor's degree chemists, with 148, in 1987-88, as it had been for the previous three years. Urbana-Champaign hung on to the second position with 130. And Chapel Hill, with 102, moved up from the fifth spot to take the third.

Berkeley produced the most chemists, 67, with bachelor's degrees certified by ACS. The University of Texas, Austin, with 49, slipped from the top spot in 1986-87 to third; Urbana-Champaign was second with 59. Certified graduates are immediately eligible for membership in ACS.

The University of California, San Diego, and the University of Rochester produced the most new master's chemists in 1987-88 with 32 each. Cornell University, the biggest producer the previous year, slipped to third with 28.

The chemistry departments at Urbana-Champaign and Wayne State University were the only two to rank in the first 25 for all categories—total bachelor's graduates, ACS-certified bachelor's graduates, masters, and Ph.D.s.

The University of Minneapolis, Minnesota, produced the most bachelor's degree chemical engineers in 1987-88, with 91.

Michael Heylin

These schools had the most chemistry graduates, 1987-88

Total bachelor graduates

1.	Indiana U	148
2.	U of Illinois, Urbana-Champaign	130
3.	U of North Carolina, Chapel Hill	102
4.	U of California, Los Angeles	78
5.	U of California, Berkeley	68
6.	U of Maryland, College Park	63
6.	U of Virginia	63
8.	U of California, Irvine	61
9.	U of Arizona	59
10.	North Carolina State U	56
11.	California Poly Tech State U	54
11.	Cornell U	54
13.	Rutgers U, New Brunswick	53
14.	U of Pittsburgh	52
14.	Youngstown State U	52
16.	St. Olaf C	51
17.	Wayne State U	50
18.	Case Western Reserve U	49
18.	Miami U	49
18.	U of South Florida	49
18.	U of Texas, Austin	49
22.	U of Michigan, Ann Arbor	47
23.	California State U, Long Beach	45
23.	U of Washington	45
25.	U of Colorado, Boulder	44
25.	New York U	44

Certified bachelor graduates

1.	U of California, Berkeley	67
2.	U of Illinois, Urbana-Champaign	59
3.	U of Texas, Austin	49
4.	U of Michigan, Ann Arbor	47
5.	U of Minnesota, Minneapolis	43
6.	U of Wisconsin, Madison	38
7.	Wayne State U	37
8.	Ohio State U	33
9.	Illinois State U	30
9.	U of North Carolina, Chapel Hill	30
11.	U of Akron	29
11.	U of California, San Diego	29
13.	Cornell U	27
14.	Michigan State U	25
15.	Indiana U	24
15.	Massachusetts Inst of Tech	24
15.	College of William & Mary	24
18.	California State U, Long Beach	23
18.	U of California, Davis	23
20.	U of California, Santa Cruz	22
20.	U of Delaware	22
20.	U of South Florida	22
23.	Bryn Mawr C	21
23.	Cleveland State U	21
23.	North Carolina State U	21
23.	Purdue U	21
23.	San Jose State U	21

Masters graduates

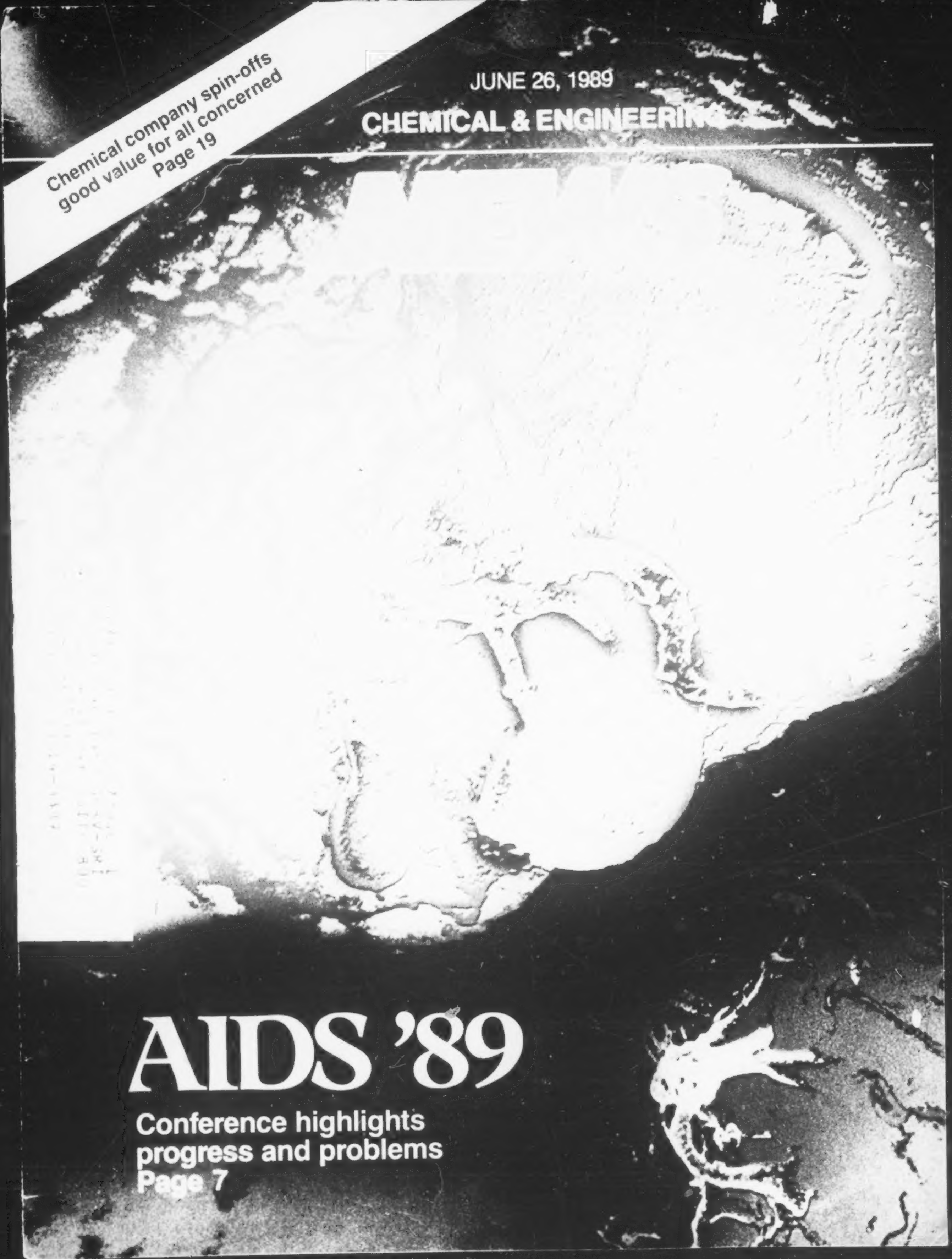
1.	U of California, San Diego	32
1.	U of Rochester	32
3.	Cornell U	28
4.	U of Illinois, Urbana-Champaign	22
4.	Northwestern U	22
6.	Harvard U	19
6.	U of Michigan, Ann Arbor	19
8.	Columbia U	17
8.	U of Connecticut	17
8.	U of Illinois, Chicago	17
8.	Wayne State U	17
12.	Texas A&M U	16
13.	U of Cincinnati	15
13.	Lehigh U	15
13.	U of Maryland, College Park	15
13.	New York U	15
13.	Princeton U	15
13.	U of Virginia	15
13.	Yale U	15
20.	California State U, Long Beach	14
20.	U of Pittsburgh	14
20.	Polytechnic U	14
20.	U of Washington	14
24.	Bowling Green State U	13
24.	Purdue U	13
24.	Rutgers U, New Brunswick	13
24.	U of Wisconsin, Madison	13
24.	Wright State U	13

Doctoral graduates

1.	U of California, Berkeley	75
2.	U of Illinois, Urbana-Champaign	43
2.	U of North Carolina, Chapel Hill	43
4.	U of Wisconsin, Madison	41
5.	Massachusetts Inst of Tech	40
6.	Ohio State U	38
7.	Iowa State U	36
8.	Purdue U	35
9.	California Inst of Tech	34
10.	U of California, Los Angeles	33
11.	Stanford U	31
12.	U of Minnesota, Minneapolis	30
13.	U of South Carolina	29
13.	Texas A&M U	29
15.	U of Florida	28
16.	U of California, San Diego	27
16.	Indiana U	27
18.	U of Chicago	26
18.	U of Maryland, College Park	26
18.	Princeton U	26
21.	U of Utah	25
22.	U of Colorado, Boulder	24
22.	Harvard U	24
22.	Michigan State U	24
25.	Northwestern U	22
25.	Wayne State U	22
25.	Yale U	22

Chemical company spin-offs
good value for all concerned
Page 19

JUNE 26, 1989
CHEMICAL & ENGINEERING



AIDS '89

Conference highlights
progress and problems
Page 7

CHEMICAL & ENGINEERING

NEWS

Volume 67, Number 26
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JUNE 26, 1989

News of the Week

- **NSF plans to send a major report to Congress on the steps needed to repair and rebuild the nation's deteriorating university and college research labs.** Page 4
- **Computerized inventory of chemical pollutants and a companion national report, both prepared by EPA, are now available to the public.** Page 5
- **Prominent chemist George C. Pimentel is dead of cancer at 67.** Page 5
- **Fire at small Connecticut custom chemical maker has triggered an arson investigation and subsequent inquiry into the possible illegal storage of phosgene.** Page 6
- **Several issues, including the best way to foster scientific cooperation, were explored at the most recent meeting of the NIH committee on the human genome project.** Page 6

Cover: AIDS virus budding from membrane of an infected lymphocyte. Photo copyright by CDC/Photo Researchers

Letters 2
Concentrates
Business 17
Government 28
Science/Technology 32
The Departments
Meetings 38
Newscripts 64

Business

Many chemical companies are splitting off businesses in effort to raise cash, focus on core businesses, improve financial performance, among other things. Page 19

Canadian chemical industry will fare well this year, but not so well as it did in 1988. Page 25

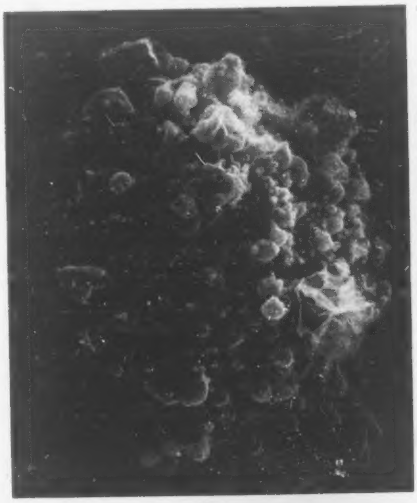
Government

President Bush announces clean air package that includes plans to tackle acid rain, urban smog, and toxic air pollution. Page 29

Science/Technology

Representatives from 80 nations gather in Helsinki, forge five-point pact that phases out use and production of CFCs and halons, and accelerates development of alternative chemicals and technologies. Page 33

Electrochemical cell uses visible light to produce hydrogen directly from seawater. Page 37



News Focus

Scientists at 5th International Conference on AIDS report progress made in treating the disease, difficulties in developing a vaccine. Conference delineated scientific and social challenges that will face humankind in the 1990s. Page 7

Chemical & Engineering News

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LETTERS

Women faculty members

SIR: Your publication is to be commended for highlighting the underrepresentation of female faculty members in departments of chemistry (C&EN, May 8, page 34). However, to judge the amount of progress being made toward equality, it is important to make an effort to use accurate data.

The conclusions drawn in your article are based on a survey taken in 1986. An hour or two of telephone calls might have revealed important changes in the numbers of female faculty members during the past three years. For example, the department of chemistry at the University of Wisconsin, Madison, currently has two female assistant professors (one full time, one joint with another department), and a third one who will arrive early next year.

I offer this information not to discount the difficulties and struggles of women to achieve equal treatment, but to correct a misrepresentation of my department. In my experience, the department of chemistry at the University of Wisconsin, Madison, offers strong and active support to all its junior faculty members, female and male.

Laura Lerner
Assistant Professor
University of Wisconsin, Madison

Mass spectral databases

SIR: We are writing in response to the item, "Faulty spectra impair utility of MS databases" (C&EN, March 20, page 40). The paragraph describes work by professors and staff at Dalian Institute of Chemical Physics in China citing some 2000 errors found in Western mass spectral databases. The errors described include incorrect values assigned to peaks, peaks from impurities including air, and mislabeling of spectra.

We would like to call to the attention of the users of the NIST/EPA/MSDC Mass Spectral Database (a joint effort of the National Institute of Standards & Technology, the Environmental Protection Agency, and the U.K.'s Mass Spectrometry Data Center), that during the past two years, a major effort has been made to locate and correct errors of the sort described by the Chinese team. From the few details given in the abstract and in a preprint of a paper describing the work of the Dalian team, we estimate that in the current version of the database (containing 50,000 spectra, released in December 1988) approximately 65% of the errors have been corrected. The intensive correction effort is still ongoing. We anticipate that the spectra included in the next release should be substantially free of these kinds of errors.

In addition, we have developed new software designed to locate errors, and have added structural information, which will permit an even higher level of error correction in the future.

Sharon G. Lias
Stephen E. Stein
NIST Mass Spectrometry Data Center
Gaithersburg, Md.

General chemistry curriculum

SIR: Sandwiched between precollege science curriculum and the training of professional chemists is the neglected question of the content of general chemistry. The precollege problem has been addressed by the American Association for the Advancement of Science and by the National Council on Science & Technology Education, and you have reported the work of each (C&EN, Feb. 27, page 4; March 13, page 22). The training of chemists is addressed by the ACS Committee on Professional Training.

The needs of students who take only one year, or perhaps two, of college chemistry are not addressed by any such committee. It is generally assumed that the first year or two years of the chemistry major's curriculum is suitable, perhaps in some diluted form. This is reinforced by some professional schools who require that applicants for admission must have taken the chemistry majors' courses in general and organic chemistry.

The assumption is usually asserted without evidence. When I have asked for the rationale, the need for academic rigor is usually mentioned, backed by a philosophy of education related to the 19th century concept of "mental muscles" and the elitist need to make the most exacting demands of students, whether or not they can meet them.

Actual needs are much different. It makes no sense that a student who takes only one year of chemistry is denied an understanding of organic chemistry, but is required to comprehend resonance and molecular orbital theory. An understanding of hydrophobicity would be of greater value than the usual explanation of why solutions of metallic

Correction

- April 24, page 35: L-Proline does not contain an indole ring.

More Companies Restructuring by Splitting Off Businesses

Selling off all or parts of selected assets enables firms to refocus operations, hike stock value and cash flow, turn around performance

Ann M. Thayer,
C&EN Northeast News Bureau

Divide and conquer. It brings to mind a strategy used against the opposition. Yet many chemical companies, or diversified companies with interests in the chemical industry, are using it as a rallying cry in internal campaigns. With hopes to refocus operations, boost stock values, turn around performance, raise cash, or distance themselves from risky or poorly performing businesses, an increasing number of companies are splitting off interests in part, or all, of selected assets. And these separated businesses also are benefiting by better focus, increased stock values, and improved financial performance.

In the past three years, W. R. Grace & Co., International Minerals & Chemical (IMC), Borden, Morton Thiokol, and Atlantic Richfield have been among those undergoing major restructurings. Other companies such as Olin and Ethyl have plans to split off nonstrategic segments to raise cash and focus on core businesses. Morton Thiokol hopes that stock prices will better reflect the value of its chemicals and aerospace divisions when separated into two companies (C&EN, March 6, page 6).

"Many of these deals are really strategic decisions to no longer be part of a given business area," says Theodore S. Semegran, a financial analyst with Shearson Lehman Hutton in New York City. "The motivation is to change the company into what it thinks it does best and what it wants its image to be. And sometimes that isn't related to whether it's the best time to sell the units, but related more to a company's philosophy."

A good example is Borden, which began scaling down its chemical operations in the mid-1980s and entered its "petrocondo" phase of leasing or selling interests in its petrochemical operations to other companies. In 1987, with a continued emphasis on its food and consumer products businesses, Borden removed itself further from the cyclical commodity chemicals business. The company sold 75% of its polyvinyl chloride, methanol and derivatives, and nitrogen products operations, including the Geismar petrochemical complex in Louisiana, through a publicly offered limited partnership.

"Here we had a commodity chemicals business, that was not in our strategic area, taking major investment," says A. S. D'Amato, executive vice president of Borden. "But we also wanted to protect ourselves from the viewpoint of supply, since about 25% of the output was being used by our downstream [film and adhesives] operations." D'Amato, who is also president of Borden's packaging and industrial products division, points out that the experience of operating the petrocondos

Several companies that recently split off from parents. . .

Company	Business	Parent[a]	Year[b]	1988 Sales	1988 Profits[c]	1988 Assets
				($ millions)		
IMC Fertilizer	Agrochemicals	IMC 38%	1987	$1086	$219	$1472
Arco Chemical	Basic chemicals	Arco 83%	1987	2700	722	2548
Lyondell Petrochemical[d]	Petrochemicals	Arco 49%	1989	4696	884	913
Borden Chemicals & Plastics	Basic chemicals	Borden 2%	1987–88	553	121	605

. . . and business units to be split off soon

Business unit	Parent[a]	1988 Sales	1988 Profits
		($ millions)	
Specialty businesses	Grace >80%	$1650	$74
Natural Resources	>80%	441	38
Grace Equipment	0%	111	12
Aluminum, Energy, and Plastics	Ethyl 0%	625	59
Unit of General Defense Corp. and others[e]	Olin 0%	na	na

a Parent company's interest after sale. b Year of stock offering. c Operating profit—sales less administrative expenses and costs of sales. d Sales, profits, and assets include refining operations. e Includes sale of photographic, ammonia, urea, and Hamilton Technology businesses. Sales anticipated to raise $190 million for Olin. na = not available.

led the company to consider other means to sell the business.

"The master limited partnership was a way for Borden to maximize the capital it would receive," explains D'Amato, owing in part to Borden's benefiting from former laws that did not tax the limited partnership as a corporation. At $10 per share, the initial 1987 offering of its plastics and chemicals operations raised $413 million. In 1988, with prices at $17 per share, Borden sold another 23% for $140 million. Left with a 2% interest in the partnership, Borden operates the business as general partner through its wholly owned subsidiary, Borden Chemicals & Plastics (BCP) Management Inc.

BCP Management (D'Amato is chairman, president, and chief executive officer of the company) has a 15-year commitment to manage the business and purchase a portion of its production output. In addition, the company guarantees a minimum return of $1.20 per share until 1992. Borden receives an incentive payment equal to 20% of operating income earned above the guaranteed minimum.

In its first full year, the BCP partnership posted earnings of $121 million based on 1988 sales of $553 million, a 5% increase over 1987 sales. Growth was attributed to higher return on sales and record low cost production of PVC, which accounted for 63% of sales. In addition, the partnership had only $19 million in capital expenditures as a result of the $500 million already invested by Borden in the eight years before the sale. In 1988, the partnership generated $19.5 million for Borden in incentives and equity interest, and a $3.02 per share cash distribution for shareholders.

George Krug, a financial analyst with Oppenheimer & Co. in New York City, views Borden's move as favorable for the company. "It clears up the product line profile," he says. "Meanwhile, you probably get more value for the whole because the parent company is no longer being penalized for having exposure to cyclical commodity swings." And, while realizing more value for shareholders and stabilizing the earnings of the parent company, it also provides those still interested in commodities with a distinct investment vehicle.

Some financial analysts view the sale of IMC's fertilizer business as another example of changing corporate focus. "They wanted to make IMC a specialty chemical company and not a fertilizer company, realizing that fertilizers are a very volatile commodity," says Krug. "IMC wanted to take the cash out of those businesses and reinvest it in other areas that had more stable earnings and growth prospects."

In the mid-1980s, IMC was struggling with businesses in the depressed energy and fertilizer industries. Hoping for a recovery in fertilizers and facing an operating loss of $108 million in 1986, the company sold off its oil and gas and industrial products businesses. Between February 1986 and March 1987, to broaden its earnings base beyond its dependence on fertilizer, the company spent close to $800 million on the acquisitions of Mallinckrodt, a specialty chemicals and medical products company, and Pitman-Moore, an animal products company. After a better year of fertilizer earnings, the company decided to sell off about 50% of its fertilizer operations to focus on its other businesses.

Before the public offering in IMC Fertilizer, it paid the parent company a dividend of $438 million. The 1987 offering of 11 million shares raised $229 million and left IMC with a 47% interest. Ironically, the fertilizer industry saw its first turnaround in five years in 1988, and IMC Fertilizer's sales reached $1.09 billion (a 24% increase over 1987) with operating earnings of $219 million (a 365% increase over 1987). With IMC Fertilizer stock selling significantly higher than at the initial sale, the company has issued 5 million shares of common stock, decreasing IMC's stake to 38% and raising money to repurchase 4 million shares of preferred stock owned by IMC.

Bolduc: focus on specialty chemicals

In separating itself from the fertilizer industry, IMC's own stock prices rose substantially between 1987 and 1988, and sales and earnings in its new core businesses of specialty chemicals, medical products, and animal products were generally better. However, total 1988 sales were down because of the decreased interest in IMC Fertilizer, but this effect was offset by the strong performance of the fertilizer business. In fact, IMC's continued interest helped support the integration of its other businesses since IMC Fertilizer, the former earnings millstone, accounted for 39% of sales and 65% of operating earnings for IMC in 1988.

IMC and Borden faced similar problems in selling off their businesses, notes Semegran of Shearson Lehman Hutton. "Each one of them had difficulties selling the deal because they were sold at very, very difficult times." IMC sold only a portion of its business. Borden's deal, falling just after the October 1987 stock market plunge, was softened for investors by the 25% ownership, financial, and management guarantees made by the company.

Yet IMC and Borden were both able to succeed in their divestitures, and, by doing so, managed to increase value for their shareholders. "Arco was another company," according to Semegran, "that thought that the best approach to the maximization of the value of a business might be to have it partly separated from the company itself." In today's takeover market, it is not unusual for companies to try to mine hidden wealth from business segments undervalued by investors.

Arco began restructuring in 1985 with the precipitous drop in the price of crude oil. Underperforming petrochemical and refining assets of the company, including its methanol and olefins operations at Channelview, Tex., and its Houston refinery, were combined to form Lyondell Petrochemical Co. In 1985, Lyondell reported a loss of $495 million, largely owing to aggressive write-downs of assets and restructuring costs.

In the following year, Arco Chemical also was significantly downsized. By selling off its building products, specialty chemicals, and Chemlink businesses, the company was restructured to focus on a strong position in its core businesses—propylene oxide, styrene, *tert*-butyl alcohol, and derivatives. By 1987, both Arco Chemical and Lyondell had become solid contributors to Arco's profits, primarily because of the boom in commodity chemicals—lower feedstock prices, increased demand, and high capacity utilization.

In 1987, Arco offered stock in Arco Chemical to the public as a means to raise cash it needed to reduce debt and repurchase stock. Another important objective was making the value of Arco's chemical operations transparent to investors and analysts. "We had a concern for a few years," says William C. Rusnack, Arco vice president for planning, "that the value [of Lyondell and Arco Chemical] was not reflected in the share price of Arco."

Rusnack describes how analysts attributed values of about $700 million to Arco Chemical and about $200 million to Lyondell in 1987. "We ended up getting out a value [on paper] in the range of $3.9 billion," he adds, "which we consider a significant improvement over what people saw prior to creating the public vehicle." Through the Arco Chemical public offering, the company raised more than $590 million from the sale of about 20 million shares and $700 million from debt placed on the balance sheets of Arco Chemical.

Business for Lyondell and Arco Chemical was very good in 1988. And, with Lyondell now a wholly owned subsidiary and Arco Chemical's results consolidated into its own, Arco received nearly 40% of its sales and nearly 60% of its net earnings from the two companies. Even with the price of oil still low, Arco was able to invest $3.3 billion in its core businesses and spend $1.2 billion on stock repurchases and dividends.

D'Amato: limited partnership is key

In late 1988, Arco decided to offer a portion of Lyondell to the public. Unlike IMC, Arco was able to sell interests in two companies when commodity chemicals were respectable investments. Lyondell paid Arco a $500 million dividend before the offering. A total of 50.1% was then sold for $1.2 billion. In terms of market value, the previously underperforming assets that make up Lyondell are now worth about $2.9 billion to the parent company.

In addition to Arco getting value out of its chemical portfolio, the move allowed analysts to view the chemicals operations separately from the oil industry. "In the case of Arco Chemical, they kept 83% of the stock, a very high degree of control, selling just a small piece to the public. But Arco does not, and will not, own a majority of Lyondell stock, so it will not be consolidated," says Bruce Jones of Moody's Investors Service in New York City. "There is an important distinction between their continuing control of Arco Chemical and their almost noncontrol of Lyondell." Arco also gets significant tax breaks on intercorporation dividends.

"When Arco Chemical or Lyondell were segments of a very large Arco company," says Rusnack, "the tremendous efforts and contributions they were making ... weren't necessarily reflected in the overall performance of Arco. So [sale of the businesses] makes sense from the standpoint of management or employee motivation." As publicly owned companies, he suggests that there may be "more immediate feedback ... with management more in sync with the shareholders and the marketplace," although he emphasizes that the parent company will remain committed to these businesses.

William H. Magee, senior vice president and chief financial officer of Arco Chemical, expresses similar feelings in describing the "subtle differences" in operating as a partially public-owned company. "We are now accountable not just to Arco as our major shareholder but to financial markets in general," says Magee. "We've gone from a world in which our capital expenditures had to be within the scheme of Arco's capital allocations to a situation in which projects have to be funded out of our own cash flow, our own borrowing capacity, and, if need be, the issuance of stock." This change, adds Magee, "tends to sharpen our focus, and I think that is helpful."

Magee explains that the company can act independently to "do the things that we need to do for the chemical company." But, he emphasizes that it was probably more the initial restructuring and focus on core products, rather than the offering of stock, that led to strong business performance in its first full year as a public company (C&EN, April 24, page 17).

Likewise, before going public, Lyondell saw a tremendous turnaround from restructuring and because of tight supply and high demand for petrochemical products. "The improvement that we had from the losses [averaging $100 million after taxes] in 1983 through 1985," explains Bob Gower, president and chief executive officer of Lyondell, "is basically a change in the way we ran the company—a change in attitude, a change in management style, and an overall change in operations."

"The restructure was strictly to see if, by putting the company together under a different format and by putting in a new management group, we could improve performance," he says. The idea that there would be "one really good effort at trying to turn the operation around," caused Arco, Gower believes, to "turn us loose and never really challenge our decisions."

"Our livelihood depended on our performance," Gower adds, "so we have always considered ourselves to be major 'owners' of the company. We ran it as an independent company as if we had done a leveraged buyout." Thus, he expects that the change in 1989 to a partially owned company will not have a large impact on how Lyondell's management runs the company.

Jones indicates that financial analysts have been following the constantly changing shape of W. R. Grace for many years. Whereas the specialty chemicals business has been its strength and has remained a constant over decades of change for the firm, he explains, the rest of its portfolio has undergone "tinkering and changing." During the past three years, restructuring moves have once again been emphasized.

Plans to restructure were accelerated in 1986 after 27% of Grace stock was placed on the market. "The company made a strategic decision in 1986, following a disastrous year in which we reported losses of $472 million," explains J. P. Bolduc, vice chairman and director of Grace, "to focus our attention and investment of capital on growing and expanding our specialty chemical business." So cash was needed to restructure and recoup the $600 million worth of stock to avoid falling stock prices or takeover attempts.

"Those two factors made the decision to divest our nonspecialty chemicals holdings an easy one," says Bolduc. "Executing it was very difficult." The company began by selling its retail and restaurant businesses. Like IMC, it also looked into selling its energy-related business and agricultural chemicals business but found that "there weren't too many takers on the street" willing to invest $600 million to $700 million for the entire agricultural chemical business at one of the worst times for the industry.

So the company broke out the fertilizer business into 100 individual businesses and through 1988 managed to sell off all but one operation. Meanwhile, the company drastically reduced the amount of capital employed in its natural resources (energy) group through divestments, write-downs, and selective sales—repositioning the group for what it hopes will be an upturn in oil and gas.

Restructuring and applying the capital from the sales to expand core businesses have resulted in a higher return for the shareholder and a higher value for Grace stock, says Bolduc. In 1988, sales for the company increased 28% to $5.8 billion with net earnings up 38% to $234 million. Specialty chemicals accounted for 54% of sales and 70% of earnings in 1988, and the natural resources group is showing a profit.

Continuing the trend, Grace announced its intention to sell minority positions (less than 20%) in its natural resources group and specialty businesses unit (C&EN, Feb. 20, page 6). The company believes that it can satisfy the capital requirements for expanding its specialty chemicals and medical products businesses without adversely affecting its interest in the other businesses. "Grace still wants to keep a percentage of ownership in those businesses," says Bolduc. "Principally because we've taken years to develop the expertise, years to build the businesses, we can now see a major recovery [in energy] around the corner. In all of our specialty businesses, the company has leading niche market positions."

Says Jones of Moody's: "The health care field now seems to have fairly lately been chosen as a principal growth thrust." Although most analysts react favorably to Grace's shift away from earlier diversifications, Jones wonders in particular what Grace can "bring to the table" in building a new position for itself in the health care field. He adds that it might be "too little, too late" for the company to enter a field that has already attracted a number of other companies for a long time.

Although specifics such as the need for cash, refocusing business, and selling off poor performers can be pinpointed as reasons that lead companies to restructure, there is also a change in attitude on the part of management. "Things are happening that are causing a number of businesses and their leadership to make decisions that heretofore they never would have dreamed of making," says Bolduc of Grace.

"It used to be that you could manage a business for the long term, for the benefit of the shareholder, and make a strategic decision today that might not build value for 10 years, but make it with the full intent of realizing above average returns for the shareholders," he says. "In today's takeover market, you can't do that." Operating a business is significantly more unpredictable than it was in the past, he adds, and management decisions are influenced by investors' demand for short-term returns and by fears of takeover.

"There is only one foolproof mechanism [against takeover], and that is the price of the stock. You have got to narrow the margin between what is perceived to be a breakup value and the current market value," says Bolduc. "The extent to which there is a gap between those two, you are vulnerable. The extent to which you close that gap, that's the defense mechanism."

"That's why restructuring goes on. That's why we are refocusing and so, too, are others," Bolduc adds. "Some would say it's better for America. I think they are right, but I think what's happening as a byproduct of that, such as the leveraged buy-out [LBO] mania, is detrimental to the economy."

The "LBO mania" doesn't address long-term interests of the company, its shareholders, or the community, Bolduc says. "If we don't awaken pretty soon, coupled with the federal deficit, I'm afraid that we could be headed for some very serious economic consequences," he notes. "It's instant gratification at the expense of long-term financial and economic viability." □

Good, but slower, growth for Canadian chemicals

The torrid pace that the Canadian chemical industry has set over the past few years may be cooling off. That doesn't mean that 1989 will be a poor year for Canada's chemical companies. It simply means that it will not be so good as last year.

Many of the signs that measure the health of Canada's chemical industry are starting to bear this out. Indexes of chemical production and shipments are leveling off or falling ever so slightly. Output of several major plastics, key components of the country's chemical industry, is down, at least through the first four months of the year.

Production of low-density and high-density polyethylene was down 4% and 6%, respectively, during the first four months of 1989. Polystyrene output was the same during this period as it was during the same period last year.

And exports, which are critically important to Canada's petrochemical industry and its world-scale plants, are also down slightly. In the first quarter, Canadian chemical exports dropped 0.4% from the year-earlier period to $1.58 billion. By itself, that slight decline is no big deal. But, combined with the industry's other economic barometers, it indicates that the industry may have to scratch harder for business, and profits, in 1989.

W. Norman Kissick, chairman and chief executive officer of Union Carbide Canada, no doubt sensed this when he addressed his firm's annual meeting earlier this year. Kissick is optimistic that Carbide Canada will be able to generate strong earnings through 1989. But, he notes, there already has been "some moderation" in petrochemical prices. And, he adds, "More can be expected with lower growth in demand."

Other chemical industry executives share Kissick's concern. They agree that 1989 should be a good year, but they also worry about weak spots along the way.

Du Pont Canada president J. E. (Ted) Newall anticipates good results in 1989. But he notes that the outlook is mixed and points to weakness in polyethylene volume and prices.

And Celanese Canada, which chalked up record first-quarter results, also faces some trouble spots. Paul H. Williams, who was president of the company until he was transferred recently to the U.S., points to higher polyester raw material costs, which can't be passed on entirely to customers. His other concerns: lower methanol selling prices and softer markets ahead for acetyl products. Williams now is vice president for fibers for apparel and home fashions of Hoechst Celanese's textile fibers group.

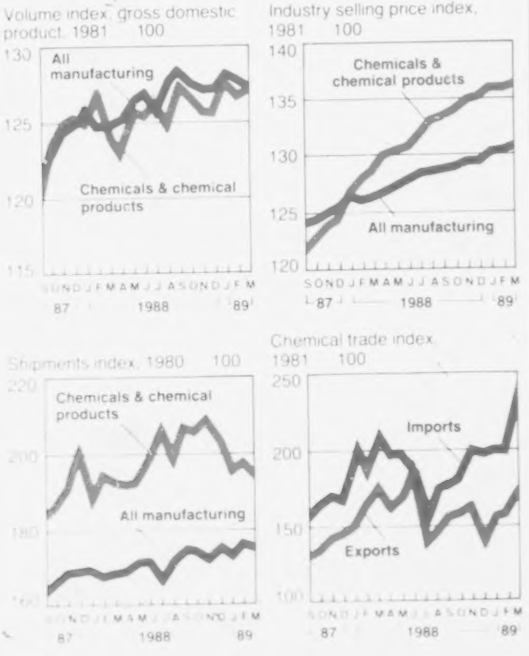
Even Nova Corp. of Alberta, which became a Canadian petrochemical giant when it acquired Polysar Energy & Chemical last year (C&EN, Sept. 12, 1988, page 10), shares other companies' concerns

Plastics output tapers off

Production, thousands of metric tons	1988	First four months 1989	First four months 1988	% change 1988-89
ORGANICS				
Benzene	695	254	247	2.8%
Butadiene	183	59	60	−1.7
Ethylene	2346	814	797	2.1
Formaldehyde	123	45	41	9.8
Methanol	2101	733	717	2.2
Propylene	669	243	206	18.0
Toluene	417	142	148	−4.1
Xylene	399	162	163	−0.6
PLASTICS				
Polyethylene, low density	1105	367	383	−4.2
Polyethylene, high density	311	102	108	−5.6
Polyesters, unsaturated	43	13	15	−13.3
INORGANICS				
Hydrochloric acid	180	61	58	5.2
Nitric acid	901	364	301	20.9
Phosphoric acid	476	184	162	13.6
Sulfuric acid	[illegible]	1304	1204	[illegible]
Ammonia, anhydrous	4010	1501	1400	7.2
Ammonium phosphate	986	319	336	−5.1
Urea	2372	864	851	1.5
Polystyrene	216	69	69	[illegible]

a [illegible] b [illegible] Source: Statistics Canada

Chemical industry growth shows signs of slowing



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about lower polyethylene prices and volume. That's because the price movements of polyethylene and other key petrochemicals have a substantial impact on Nova's profit margins.

Earlier this year, Nova cut the capacity of an ethylene plant—its third—that it will build at Joffre, Alberta. Nova's explanation: not enough customers to justify building the unit as it was originally designed.

Nova's original plan called for a 680,000 metric-ton-per-year ethylene unit. When the $420 million plant comes on stream in late 1992, capacity will be closer to 540,000 metric tons.

Nova's ethylene retrenchment doesn't seem to be affecting other ethylene expansion plans in Canada. Polysar, for instance, is expanding its capacity at Corunna (Sarnia), Ontario, by 20% to 545,000 metric tons.

Meanwhile, Dow Chemical Canada, a major ethylene consumer, is building its own ethylene plant at Fort Saskatchewan, Alberta. Its 500,000 metric-ton-per-year plant is scheduled to be on stream in 1993.

In fact, capital spending plans for all types of plants for the Canadian chemical industry this year remain very ambitious. According to Statistics Canada, the industry will spend an estimated $1.3 billion on capital projects in 1989, a hefty 42% more than last year. Additional spending on plant repairs and upgrading will boost the total to $1.9 billion.

Carbide Canada will boost capital spending this year 25%, after a huge 60% increase last year. Much of the spending is earmarked for air separation plants. The company also is building a methyl diethanolamine plant in Montreal East.

However, the company's spending in the Montreal area could jump sharply if studies now under way bear fruit. Carbide is considering expanding olefins capacity at Pétro-

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mont, the Montreal-based petrochemical producer owned jointly by Carbide and the Quebec government. Another possibility: modernizing and upgrading Pétromont's polyethylene plant. Total spending on these possible Pétromont projects could hit $126 million.

Among other major chemical projects on the Canadian chemical construction schedule is a new hydrogen peroxide plant that Du Pont Canada will build at Gibbons, Alberta. The plant will have a capacity of 36,000 metric tons per year and cost about $100 million. Its planned startup is in 1991.

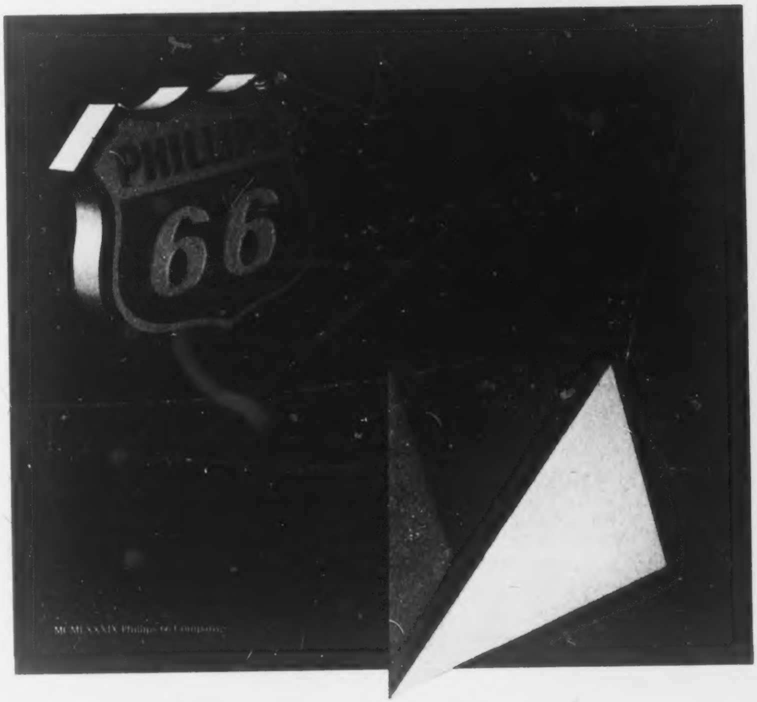
And Finland's Neste Oy, along with new partner Petro-Canada, will build a 500,000 metric-ton-per-year plant to produce methyl *tert*-butyl ether at Edmonton, Alberta. The $252 million project is slated for completion by the second half of 1991. Petro-Canada replaces Trans Mountain Pipe Line, Neste's original partner in the venture.

In British Columbia, Westcoast Energy and its Taiwanese partners are looking into the possibility of building ethylene glycol and polyethylene plants. Himont Canada and Shell Canada are boosting polypropylene capacity. And Esso Chemical Canada, one of the only two Canadian producers of polyvinyl chloride, is expanding capacity of its Sarnia PVC plant by 30,000 metric tons from the current capacity of 100,000 metric tons annually.

These and several other major new plant and expansion projects in the chemical industry will boost the industry's production capacity substantially. The big question is, are these projects coming at a time when the industry's fortunes may be due for a reversal? If so, some of them no doubt will be scratched or at least delayed.

As usual, much will depend upon the economy. Many economists in Canada think that the economy is heading into recession, if not this year, then in 1990. One reason is interest rates, which are high and expected to remain high. Inflation, too, could become a problem if Canada's new sales tax pushes prices higher than the government anticipates.

Earl Anderson



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CALENDAR OF EVENTS
Scientific meetings
Page 41

JULY 3, 1989

CHEMICAL & ENGINEERING NEWS

SALARY SURVEY

Chemists' salaries continue to rise as unemployment remains low
Page 31

CHEMICAL & ENGINEERING
NEWS

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JULY 3, 1989

News of the Week

- **House subcommittee hearing and NIH forum addressing issue of research integrity give hopeful indication that those on both sides of the issue are coming to some accord.** Page 6
- **Altered version of tissue plasminogen activator, engineered by Texas researchers, may turn out to be an improved anticlotting agent.** Page 7
- **The American Chemical Society held a full-blown press conference in New York City last week aimed at increasing the society's visibility to the public.** Page 7
- **President Bush names Johnson & Johnson's Gerard F. Scannell as head of the Occupational Safety & Health Administration.** Page 8
- **Canada may raise tariffs on U.S. chemicals and plastics products in retaliation for a U.S. Superfund tax on imported oil.** Page 8
- **CFC producers are accelerating the pace of developing alternatives that don't deplete the stratosphere's ozone layer.** Page 8

Business

Prices drop for basic aromatic chemicals, following increase in production and rise in inventories; BP Chemicals boosts world capacity for acetic acid with new plant at its chemicals complex in Hull, England; Austria's Lenzig A.G. eyes U.S. for growth in firm's polyimide fiber market with purchase of Allco Chemical. **Page 11**

Government

Hearings, reports on solid waste problem bring more Congressional attention to disposal dilemma; EPA Administrator Reilly offers new Superfund strategy. **Page 23**

Science/Technology

Oil industry unveils five-year research, cleanup, and prevention plan to combat future large spills. **Page 28**

Books

In "The Acid Rain Controversy" James L. Regens and Robert W. Rycroft miss the mark by focusing on information pertaining to the U.S., failing to mention important Canadian data. **Page 36**

Meetings

C&EN's semiannual calendar lists meetings and other events of interest to chemists and chemical engineers. **Page 41**

Salary Survey

Chemists' salaries are moderately higher this year; the most recent ACS survey shows median salaries up 5% from the year before, about in line with the rise in living costs. Unemployment among chemists remains at about 1.0% for the third year in a row. **Page 31**

Cover: Photo by Gordon Kurzweil/Uniphoto Picture Agency

Letters 4

Concentrates
Business 9
Government 20
Science/Technology 26

The Departments
Software/Database Update 30
ACS Comment 39
Newscripts 60

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LETTERS

Stereotyping scientists

SIR: Why can't chemists, or scientists in general, do what nurses and secretaries, and several other kinds of people, have been doing recently? According to a report in the *New York Times* on April 23, 1989, there have been strong (and well-justified) objections to the portrayal of nurses as stupid sluts in the TV series "Nightingales." As a consequence of pressure on advertisers, the owners of the series have promised to clean up the act next season, and even to snip out some explicit sex scenes from the summer reruns. Secretaries are objecting openly to the airhead stereotypes in TV shows and movies—and they are getting some results. I read, a couple of years ago, that some standup comics in New York were getting laughs by using "Bruce" as a running-gag name for homosexuals. They were, somehow, persuaded to desist.

The stereotype for scientists is "mad," or "evil genius." Oh, yes, that's merely on TV and in movies; and who takes them seriously? Well, just who absorbed the stereotype of Jews, based on Shylock in "The Merchant of Venice"? Millions and millions of people, that's who. It is the images that we receive, over and over again (especially when young) that get into our subconsciousness and that bias people against particular groups—whether Jews, or secretaries, or nurses, or men named Bruce, or chemists.

Can't we start a campaign to redeem the good name of scientist from the subconscious hostility that TV, movies, and novels generate? Movies don't need to portray scientists as wanting to cut up a cute, innocent little extraterrestrial!

If we are to compete with Japan in technology, we can't afford to have our young people turned off by antiscience, antichemistry images, which subtly direct them away from careers in science and engineering.

Robert J. Good
SUNY, Buffalo

Clarification of credit

SIR: In a recent letter (C&EN, June 12, page 3), John J. Eisch of the chemistry department, State University of New York, Binghamton, wrongfully takes us [*J. Am. Chem. Soc.*, **111**, 2316 (1989)] and the Science/Technology Concentrates section of C&EN (March 27, page 26) to task for reporting the isolation of potassium boratirene, and implies that we were deceptive by ignoring his previous findings.

Readers of C&EN may be interested to know that in our communication we give full credit to Eisch for his earlier work: "and Eisch's report that photolysis of. . . ." In our communication we properly report the "first isolation and characterization of a boratirene" (an unsaturated three-membered ring compound containing a tetravalent boron atom). The claim we make for novelty is accurate.

Furthermore, we never allege being the first to observe di-π-methanelike photochemical rearrangements of borates. Indeed, analogous rearrangements were reported by Williams and coworkers in a series of papers dating back to the 1960s [see, for example, *J. Org. Chem.*, **36**, 544 (1971)].

In his recent letter, Eisch raises questions concerning the x-ray structure and optical absorption spectrum of tetraphenylboratirene. These issues will be addressed in their proper forum in due course.

Gary B. Schuster
Michael A. Kropp
Urbana, Illinois

Fast-curing cement

SIR: The excellent article by Pamela Zurer on the fast-curing cement Pyrament (C&EN, Feb. 13, page 37) has exposed several American cement experts and chemists to the debate on the novelty of the formulation. On the one hand, Lone Star's spokesman says, "We're absolutely not going to disclose how we do it." On the other hand, D. M. Roy states, "It would take a fair amount of trouble to find out what's in it, but it probably could be done."

From a European point of view I am surprised at our American colleagues' lack of curiosity. It took us only two days to analyze and find out the formulation of the latest Pyrament brand.

I must admit that, as the primary inventor, I was immediately able to recognize the various ingredients and compounds.

One of the latest published Lone Star patents has confirmed our analytical results. Page 4 of the specification (international publication WO89/02878) outlines the vital role played by the geopolymeric compounds involved in the hardening mechanism with regular portland cement. I quote: "However . . . the inclusion of metakaolin (geopolymeric precursor) is preferable where the utilization in the composition at temperature below the freezing point of water is contemplated. When little or no metakaolin (geopolymeric precursor) is present, there is less durability in the

Oil Industry Unveils Program To Combat Major Spills

Five-year plan for cleanup, prevention, research to cost $250 million, but critics push for tighter controls on oil operations

Richard J. Seltzer, C&EN Washington

Murray: speed, decisiveness critical

Seeking to prevent another spill like the disastrous Alaska oil spill of three months ago, a top-level task force, composed of chief executives or presidents of eight major oil companies, unveiled a comprehensive industry oil-spill program late last month. The firms include Amoco, Atlantic Richfield, BP America, Chevron, Exxon, Mobil, Shell, and Texaco.

Costing more than $250 million over its first five years, the plan deals with prevention, containment, and cleanup of major spills, and research on spill control and mitigation (C&EN, June 26, page 32). The task force was formed in early April by the American Petroleum Institute (API) in response to the massive spill of March 24, when the tanker *Exxon Valdez* released almost 11 million gal of North Slope crude oil into the pristine waters of Prince William Sound—the largest oil spill in U.S. history.

However, the program unveiled at a press conference in Washington, D.C., does not seem to be restoring credibility to the industry, nor to be heading off controls moving through Congress. The program has been greeted skeptically by environmentalists and some members of Congress, who seek legal mandates rather than voluntary actions.

For example, says Rep. George Miller (D-Calif.), chairman of the House Interior Subcommittee on Water, Power & Offshore Energy Resources, "Congress will not rely on the promises of the oil industry. The capability of the industry to respond to major oil spills must be a matter of law, not promises." Adds Sen. Ted Stevens (R.-Alaska), sponsor of a comprehensive oil-spill bill that passed the Senate Commerce Committee on June 20, "there were firm commitments" from Exxon and the Alveska Pipeline Service Co. "to prevent oil spills, and they were not kept." And at press time the House Appropriations Committee was preparing to vote on a drilling moratorium covering several East Coast and West Coast offshore sites, including Alaska's Bristol Bay.

Research program to cost more than $30 million

$ Thousands per year[a]	Years 1-2	Years 3-5
Preventing loss from or retaining oil near ship	$ 150	$ 150
On-water oil recovery & treatment	2650	1850
Preventing & mitigating shoreline impact	3450	1675
Fate & effects of oil in the environment	2100	1100
Wildlife preservation	700	150
Health & safety issues	300	50
TOTAL PER YEAR	$9350	$4975
TOTAL FOR FIVE YEARS	$33,625	

Note: Effort expected to continue at $1 million to $4 million a year after initial five years. [a] Estimated.
Source: American Petroleum Institute

Moreover, the oil industry's image suffered another black eye on June 23-24, three days after unveiling of the industry plan, when tanker accidents caused oil spills at three widely separated sites within a 24-hour period. Hundreds of thousands of gallons were released at each site—off Newport, R.I., in the Delaware River; and in the Houston Ship Channel.

Indeed, these developments reinforce the judgment by many observers that the *Exxon Valdez* spill was a watershed event, casting doubt on the oil industry's competence and credibility in the way that the explosion of space shuttle *Challenger* rocked the U.S. space program. The efforts by Exxon and Alveska to deal with the spill have been widely denounced as "unreasonably slow," "confused," and "inadequate," including strong criticism in a report to President Bush by the Environmental Protection Agency and Department of Transportation (C&EN, May 29, page 4).

Nevertheless, in presenting the industry's program at the press conference, task force chairman Allen E. Murray tried to accentuate the positive. Murray is chairman, president, and chief executive officer of Mobil Corp. "Industry has a very good record," with more than 99% safety in transporting oil, he noted. Most spills are relatively small, and industry responds well to noncatastrophic spills.

The new program is aimed, therefore, at the infrequent "catastrophic" spills, which are low-risk, high-cost accidents. "These costs include the impact on the environment, the cost to other affected parties, the cost of cleanup, the loss of industry reputation, loss of time to conduct normal business, the loss of business opportunities, and an increased regulatory burden," notes the task force's report.

The size of a spill alone does not define "catastrophic": the type of oil and spill location are also critical. But for planning purposes the group uses 30,000 tons (216,000 barrels or 9.1 million gal) as the threshold, almost the size of the Alaska spill. At present, the report emphasizes, "The industry is not prepared anywhere along the coastal U.S. to deal with a spill of this size."

The program provides a three-pronged attack—tightened standards and improved safeguards for tanker operations; establishment of a Petroleum Industry Response Organization (PIRO) prepared to move quickly to control major spills; and funding of an extensive new R&D program.

"Prevention must continue to be the first line of defense against spills," Murray points out. "This means heavy emphasis on avoiding tanker accidents."

However, the main thrust is establishment of PIRO, with headquarters in Washington, D.C., and five regional response centers covering all coasts. PIRO's goal will be to deploy equipment in response to a 30,000-ton spill within five hours.

"Speed and decisiveness are critical to effective spill response," Murray stresses, "and the procedures in place in the U.S. are hardly conducive to either." Therefore, a key proposal is that the Coast Guard manage major spills, with PIRO providing equipment and personnel. "We need to react immediately," says Murray, with clear-cut authority for such time-critical steps as chemical dispersant use, so as "not to start testing chemicals when oil is on the water."

PIRO's headquarters would carry out research and training, maintain a data bank, and coordinate responses. Regional centers are proposed for the major ports of New York City; Norfolk, Va.; New Orleans; Seattle; and Long Beach, Calif. Total staff would be about 285. Each center would be staffed around the clock and would be capable of responding to a 30,000-ton spill. For larger spills, two or more centers could be mobilized. In addition, Alyeska is to set up a similar oil response center in Valdez, Alaska.

The task force hopes to have PIRO operating by next summer. So far, 14 firms representing about three quarters of oil shipping have agreed to share costs. It will cost $70 million to $100 million to set up the centers, and $30 million to $35 million a year to operate them.

Throughout the report, needs for research are emphasized. The task force proposes an R&D program of $30 million to $35 million over the next five years, covering the spectrum from basic science (for example, better understanding of the chemical, physical, and biological effects of oil on the environment) to operations (such as use of containment booms in high seas). Priority will go to areas with the greatest potential benefits.

Relatively little progress has been made in the past decade in R&D on oil-spill control and cleanup, notes Eugene A. Renna, president of Mobil's marketing & refining division. Renna explains to C&EN that "there was so much pressure to work on other areas of the environment" that oil spills were put on the back burner. Mechanical devices, such as booms and skimmers, have not advanced greatly. "But not enough has been done on chemical dispersants, either, for example for cold water or freshwater use."

PIRO will contract its research to outside labs, and will cooperate with federal labs, API, individual oil firms, and others. "This is a very large increase in funding for oil-spill research," notes Charles J. DiBona, API president and chief executive officer. The effort is front-loaded to build an enlarged technical base, with $9.4 million allocated for each of the first two years, and $5 million for each of the next three, followed by a projected effort of $1 million to $4 million a year.

R&D on chemical dispersants will get high priority—$1 million of the $2.65 million allocated in each of the first two years for "on-water oil recovery and treatment." In addition in the same category, sorbents, gels, and elastomers will receive $250,000 a year in the first two years. Bioremediation—the use of microbes to biodegrade oil in situ—also will have high priority, receiving $2 million a year in the first two years from the budget for "preventing and mitigating shoreline impact." And research on the biological fate and effects of oil will get $1.5 million a year for the first two years. ☐

U.S. Coast Guard photo

Boats and booms clean up* Exxon Valdez *oil spill in Alaska's Saw Mill Bay

Chemists' Salaries Are Higher; Unemployment Remains Down

This year, as in the two previous years, the employment situation for U.S. chemists seems essentially sound. Returns from the most recent annual survey made by the American Chemical Society of its members' economic status, conducted this past spring, show that very few chemists are involuntarily unemployed.

Only 1.0% of chemists reported that they were jobless and seeking work last March, an unemployment rate essentially unchanged since 1987. In fact, the unemployment rate among chemists has never been significantly below that level since ACS began surveying employment among its members in 1971, which suggests that 1% probably represents as low a level of unemployment as is likely for the profession.

This year, too, the rate is quite similar almost across the board; in the past, women chemists were somewhat more likely to be unemployed than men, and minority chemists more likely than whites. As in previous years, however, the jobless rate for chemists who do not have a graduate degree is a bit higher than that for those who do. The overall rate of unemployment this year is less than half what it was when it hit 2.2%, its highest level in over a decade, six years ago.

Chemists report, too, that they are making more money this year. Median base salaries for chemists, as of March 1, are 5% higher than a year earlier, whatever their level of training. This rate of increase is in line with the average annual growth in salaries over the past 10 years or so.

But the Bureau of Labor Statistics' index of consumer prices likewise increased 5% in the 12 months through March 1989. So factoring the rate of inflation into the picture, the recent salary improvement essentially is wiped out. In fact, after adjustment for higher living costs, the median salary for chemists with either a B.S. or an M.S. degree is a bit less this year than it was in 1980. And for those with a Ph.D., the median, in constant dollars, is only slightly higher now than it was then. Individuals would have fared better, to be sure, be-

Unemployment is low for ACS members, whatever their gender, training, or background

	Chemists										
		By sex		By highest degree			By minority status		Chemical engineers	All members[c]
Employment status[a]	Total	Men	Women	B.S.	M.S.	Ph.D.	Minority[b]	Nonminority		
Employed full time	94.4%	95.2%	90.8%	95.5%	95.7%	93.6%	91.8%	94.6%	94.6%	94.4%
Employed part time	1.5	1.0	3.6	1.4	1.8	1.4	1.8	1.5	1.7	1.5
Postdoctoral or fellowship	2.1	2.0	2.8	0.1	0.1	3.6	5.2	1.9	0.6	2.2
Unemployed										
Seeking employment	1.0	1.0	1.0	1.5	1.1	0.8	0.7	1.0	1.5	1.0
Not seeking employment	0.9	0.7	1.9	1.5	1.3	0.6	0.5	1.0	1.6	0.9

a As of March 1, 1989. b Black, Spanish/Hispanic, American Indian, Alaskan native, Asian, Pacific Islander, or other. c Includes ACS members whose highest degree and present work are in neither chemistry nor chemical engineering. **Source:** ACS survey

Increase of 5% in chemists salaries in past year is in line with recent trend

											Annual change		
$ Thousands	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1988–89	1984–89	1979–89
CHEMISTS' MEDIAN SALARIES[a]														
B.S.	$37.0	$35.4	$33.5	$33.0	$32.0	$30.9	$30.0	$28.5	$27.5	$25.0	$23.5	5%	4%	5%
M.S.	43.0	41.0	39.0	37.9	36.0	34.0	33.0	31.6	30.0	26.0	25.0	5	5	6
Ph.D.	52.5	50.0	47.7	47.8	44.0	42.0	40.0	37.5	35.0	31.2	29.0	5	5	6
All chemists	47.3	45.0	42.5	42.5	40.0	38.0	36.0	34.7	32.0	28.9	na	5	4	na

a Base annual salary as of March 1. **na** = not available. **Source:** ACS survey

Salaries tend to rise most markedly during the first 20 to 30 years of a chemist's career

Years since B.S. degree	Median salary ($ thousands)^a 0 to 1	2 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 or more	Overall
NONACADEMIC CHEMISTS											
B.S.											
90%	$31.5	$35.0	$43.0	$50.9	$58.0	$66.4	$70.0	$76.0	$ 88.0	$ 71.0	$60.0
75%	28.5	31.0	37.0	44.1	50.0	57.4	60.0	60.0	65.9	59.1	48.4
50%	25.5	26.9	32.0	38.0	42.0	47.9	48.4	50.0	55.9	51.8	37.4
25%	21.3	23.0	27.9	31.9	35.2	40.2	40.0	40.0	44.9	40.0	29.4
10%	19.3	20.0	24.6	26.5	30.0	30.3	32.0	35.0	35.0	33.0	24.2
M.S.											
90%	—	37.0	44.0	52.0	62.0	70.8	74.6	72.0	80.0	86.0	66.6
75%	—	35.0	39.1	46.2	55.0	60.0	60.0	66.6	63.9	66.0	56.0
50%	—	33.0	35.0	40.2	44.5	50.0	53.1	54.8	53.0	58.6	45.0
25%	—	29.0	31.2	36.0	39.0	41.0	43.0	45.0	45.0	50.0	37.0
10%	—	26.3	27.0	31.2	34.5	32.5	36.6	37.0	40.0	43.0	31.2
Ph.D.											
90%	—	—	50.0	60.0	72.0	84.0	91.0	91.6	102.0	100.0	84.0
75%	—	—	47.1	53.6	61.1	72.0	77.7	77.0	85.0	79.6	70.0
50%	—	—	44.3	48.5	55.0	62.0	65.5	66.2	70.6	69.0	57.0
25%	—	—	41.5	44.0	48.0	52.1	55.9	55.0	60.0	55.0	47.5
10%	—	—	38.7	40.0	42.2	45.0	45.0	45.7	50.1	46.0	42.0

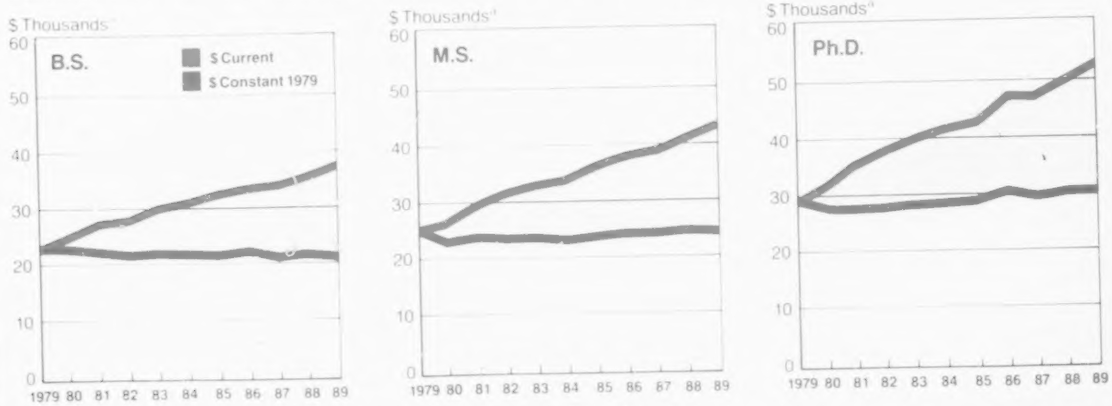
How to read this table: Using, as an example, nonacademic B.S. chemists two to four years after they have received their B.S. degree, 90% of these chemists have annual base salaries of $35,000 or less, 75% have annual base salaries of $31,000 or less, 50% have annual base salaries of $26,900 or less, 25% have annual base salaries of $23,000 or less, and 10% have annual base salaries of $20,000 or less as of March 1, 1989. a As of March 1, 1989. **Source:** ACS survey

cause their own salaries depend not only on the overall level of salaries for all members of their profession but also on how long they have been active in their career.

Few chemists, of course, actually earn a salary at the median level for the profession as a whole. (The median is the salary that is exceeded by 50% of the respondents to the survey; it indicates more accurately than the mean a typical salary for a group of individuals.) To compare one individual's earnings with those of his or her peers, therefore, it is more meaningful to look at median salaries for smaller, more similar groups within the profession. Salaries are dependent on the type of work that chemists do, who they work for, and how long they have been working, among other things.

One thing clearly evident is that women chemists continue to earn less than their male colleagues. In part, this is because women, as a group, have less experience. For example, nearly 80% of the nonacademic respondents who are women received their B.S. degree less than 20 years ago, compared with only about half the men. But even adjusting the salaries to account for this difference, the averages (rather than the medians) for women's salaries are still only roughly 80 to 90% those of men, a differential that has not changed significantly during the past half dozen years or so. The gap typically is relatively slight—or even nonexistent—between less experienced men and women chemists but

Salaries of chemists continue to climb, but are relatively static if adjusted for inflation



a Median base annual salary for chemists employed full time as of March 1 of each year. **Source:** ACS survey

Industrial chemists' salaries vary from industry to industry

Industry	% of industrial chemists: All chemists	B.S.	M.S.	Ph.D.	Mean salary ($ thousands)[a]: B.S.	M.S.	Ph.D.
Pharmaceuticals[b]	18%	16%	21%	19%	$42.4	$50.7	$64.9
Specialty chemicals	15	15	14	16	45.7	51.3	61.6
Basic chemicals	7	4	5	9	46.3	50.0	64.6
Plastics	6	6	5	7	46.2	52.2	64.2
Electronics	5	4	5	5	46.2	52.5	62.2
Petroleum and natural gas	4	4	3	5	44.4	56.3	69.5
Food	4	5	4	3	41.5	49.6	59.9
Coatings	4	6	4	3	41.6	48.5	56.3
Agricultural chemicals	3	3	3	4	37.5	47.3	62.2
Metals and minerals	2	3	3	1	39.6	46.1	56.1
Biochemical products	2	1	2	3	38.7	52.7	61.1
Rubber	2	2	1	1	45.5	50.8	57.1
Soaps and detergents	1	2	1	1	39.4	53.4	57.3
Paper	1	1	1	1	41.8	44.7	54.4
Other manufacturing	15	15	16	14	42.1	50.5	58.9
Nonmanufacturing	10	14	12	7	39.0	48.2	61.2

a As of March 1, 1989; to facilitate comparison, mean salaries are adjusted for differences in average length of experience for each group. b Includes personal care products. **Source:** ACS survey

widens markedly as their careers lengthen.

At least part of the reason probably lies in differences in the type of work or the level of responsibility that show up between men and women. In industry, men chemists are twice as likely as women to hold management positions, the jobs for which salaries tend to be highest. In addition, nearly 30% of the women report they work as analytical chemists, compared with only about 20% of the men, and women also are more likely than men to hold jobs as biochemists or environmental chemists. These are specialties for which salaries typically are lower than those, for example, in materials science, physical chemistry, or polymers, specialties where men are overrepresented.

Similarly, in the academic community, relatively few women have attained the rank of full professor. Only 26% of the women on the chemistry staffs of colleges and universities are full professors, another 26% are associate professors and 29% are assistant professors. In contrast, 56% of the men are full professors, whereas only 19% are associate and 15% assistant professors. Moreover, only 45% of the men responding to the survey but nearly two thirds of the women teach at schools that do not have a Ph.D. program, where salaries generally are lower than those paid by Ph.D.-granting universities.

Base salaries are not the only remuneration that chemists may earn, to be sure. About 45% of the industrial chemists responding to the sur-

In academia, full professors earn considerably more than those ranked lower

Years since B.S. degree	Median salary ($ thousands)[a]: 5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 or more	Overall
Ph.D. CHEMISTS EMPLOYED FULL TIME IN ACADEMIA									
Ph.D.-granting schools									
Professor	—	—	$61.2	$62.2	$65.3	$69.3	$67.0	$82.2	$67.1
Associate professor	—	$48.0	48.8	45.6	46.2	(50.0)	—	—	48.3
Assistant professor	$40.1	40.3	40.5	—	—	—	—	—	40.3
All ranks[b]	37.2	40.3	47.6	54.9	59.6	67.1	65.6	76.7	54.9
Non-Ph.D.-granting schools									
Professor	—	—	(46.0)	51.0	51.2	55.4	56.8	60.0	53.2
Associate professor	—	(45.1)	40.9	43.9	41.5	43.0	—	—	42.7
Assistant professor	35.4	34.2	31.1	(34.0)	(42.7)	—	—	—	34.2
All ranks[b]	31.7	34.2	35.4	45.1	48.4	52.4	54.9	58.6	45.1

Note: Where no salary data are shown, sample is too small to provide a meaningful figure; data in parentheses are from relatively small samples as well, and should be viewed with caution. a Base annual salary as of March 1, 1989, excluding summer teaching and other supplemental earnings; salaries of the approximately 60% of academic chemists who have nine- or 10-month contracts are adjusted to a 12-month basis. b Includes instructors, lecturers, research associates, and others not listed separately. **Source:** ACS survey

Salaries of women chemists range about 10 to 20% below those of their male colleagues

Mean salary, $ thousands[a]	B.S.: All chemists	Men	Women	Women as % of men	M.S.: All chemists	Men	Women	Women as % of men	Ph.D.: All chemists	Men	Women	Women as % of men
EMPLOYER												
Private industry	$41.6	$44.5	$37.6	85%	$48.8	$50.6	$44.1	87%	$62.3	$63.3	$54.8	87%
Academic	28.5	32.5	24.7	76	34.5	37.4	29.7	79	46.6	47.7	39.8	83
Government	36.9	38.7	35.2	91	41.0	43.4	39.1	90	54.2	55.4	44.2	80
Other	40.3	44.3	33.4	75	48.9	51.2	43.5	85	60.8	62.9	50.0	79

a As of March 1, 1989; to facilitate comparison, women's salaries are adjusted for the difference in average length of experience between them and men. **Source:** ACS survey

Research chemists tend to earn less than managers, women less than men in industry

Years since B.S. degree		Median salary ($ thousands)[a]										
		0 to 1	2 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 or more	Overall
CHEMISTS EMPLOYED FULL TIME IN INDUSTRY												
Sex												
Men	B.S.	$26.0	$28.8	$34.0	$40.0	$44.0	$50.0	$53.4	$55.0	$56.6	$54.0	$41.0
	M.S.	—	(34.2)	36.5	41.0	46.8	54.0	54.2	55.3	56.0	59.6	48.0
	Ph.D.	—	—	44.8	49.8	55.5	64.0	69.1	68.5	74.0	72.0	59.6
Women	B.S.	25.6	26.4	31.0	38.0	39.2	36.2	40.0	(42.0)	—	—	31.0
	M.S.	—	(33.0)	34.5	40.0	42.4	44.5	(42.0)	(49.9)	—	(60.0)	39.3
	Ph.D.	—	—	45.0	48.0	55.3	61.8	(48.0)	(51.6)	—	—	48.0
Work function												
General management	B.S.	—	—	38.0	42.7	43.2	(49.0)	(48.0)	(62.0)	70.2	—	45.0
	M.S.	—	—	(37.6)	41.0	(49.9)	(49.7)	(51.6)	(55.0)	(76.2)	(60.0)	48.3
	Ph.D.	—	—	—	—	59.5	68.0	82.3	85.0	100.0	(69.4)	73.0
R&D management	B.S.	—	—	—	45.8	(54.0)	(54.5)	(64.5)	(60.0)	61.8	—	55.0
	M.S.	—	—	—	(47.5)	59.5	60.8	(61.5)	(67.8)	60.0	(66.3)	58.0
	Ph.D.	—	—	(46.6)	54.5	65.0	72.5	75.0	79.5	86.0	88.0	72.2
Basic research	B.S.	(29.0)	28.2	32.0	(36.8)	(39.7)	—	—	—	—	—	31.1
	M.S.	—	—	34.1	40.2	43.0	—	(54.0)	—	—	—	42.0
	Ph.D.	—	—	44.0	49.7	52.8	62.2	63.0	68.4	66.6	—	53.0
Applied research[b]	B.S.	26.7	28.0	33.0	38.0	41.4	43.0	45.0	46.4	51.0	(46.1)	36.0
	M.S.	—	(33.4)	36.2	40.0	42.6	50.0	54.5	47.0	56.5	60.0	43.0
	Ph.D.	—	—	45.0	48.0	53.0	58.7	63.0	62.8	63.8	63.1	53.0
Production[c]	B.S.	(25.5)	25.0	31.9	35.5	38.0	(50.6)	46.0	(48.2)	(50.5)	—	35.0
	M.S.	—	—	(35.5)	39.6	43.0	44.0	(48.0)	(55.3)	(50.0)	—	42.6
	Ph.D.	—	—	—	(44.0)	(46.0)	53.6	(58.0)	(54.1)	—	—	53.0
Marketing[d]	B.S.	—	28.4	32.5	40.0	50.6	52.5	(50.0)	(60.5)	(57.3)	—	44.0
	M.S.	—	—	(36.0)	40.5	50.6	(47.3)	(56.5)	—	(51.5)	—	47.0
	Ph.D.	—	—	—	(49.8)	(57.5)	66.7	(64.0)	(58.5)	—	—	57.0
Work specialty												
Agricultural and food chemistry	B.S.	—	—	(30.1)	(39.5)	—	—	—	—	(53.0)	—	40.0
	M.S.	—	—	—	—	—	(43.0)	—	—	—	—	48.6
	Ph.D.	—	—	(45.0)	45.9	(52.8)	(53.1)	64.0	(70.5)	(67.4)	—	54.0
Analytical chemistry	B.S.	25.4	26.2	32.9	37.2	40.8	46.1	50.0	45.8	49.8	—	35.0
	M.S.	—	—	35.0	40.0	42.0	51.1	49.3	50.5	(55.0)	(60.0)	42.8
	Ph.D.	—	—	45.0	47.0	55.0	62.5	65.0	60.8	70.3	(72.3)	52.0
Biochemistry	B.S.	—	(28.9)	(35.6)	—	—	—	—	—	—	—	34.3
	M.S.	—	—	(34.8)	(39.6)	(48.0)	—	—	—	—	—	40.0
	Ph.D.	—	—	(46.0)	50.0	53.6	68.5	(55.9)	(63.5)	(94.0)	—	54.6
Environmental chemistry	B.S.	(22.0)	26.0	33.2	40.9	(39.3)	(46.0)	—	(48.0)	—	—	37.0
	M.S.	—	—	(35.0)	40.5	(44.3)	—	—	—	—	—	43.0
	Ph.D.	—	—	—	—	(53.0)	63.7	(59.5)	—	(90.0)	—	54.5
Inorganic chemistry	B.S.	—	—	(31.8)	—	—	—	—	—	—	—	39.0
	M.S.	—	—	—	—	—	—	—	—	—	—	(48.5)
	Ph.D.	—	—	(46.5)	52.6	53.9	(67.0)	(78.8)	—	—	—	56.8
Materials science	B.S.	—	(29.6)	(30.0)	(40.0)	(40.0)	—	—	(57.8)	(75.0)	—	40.0
	M.S.	—	—	—	(37.9)	—	(60.0)	(50.0)	—	(55.5)	—	52.0
	Ph.D.	—	—	(45.9)	50.8	55.0	63.5	69.6	(66.9)	(65.0)	(68.1)	60.0
Medicinal and pharmaceutical chemistry	B.S.	—	(31.1)	(34.8)	(35.0)	(43.3)	(48.8)	—	—	—	—	36.8
	M.S	—	—	(34.2)	(38.2)	(47.0)	(50.9)	(51.0)	—	—	—	43.0
	Ph.D.	—	—	(45.2)	52.2	57.6	69.0	78.0	(71.5)	80.0	(71.3)	61.2
Organic chemistry	B.S.	—	28.0	30.5	40.0	(43.8)	(44.5)	(46.8)	(55.5)	(52.5)	—	38.9
	M.S.	—	—	(35.2)	41.4	45.0	(49.0)	(54.1)	(48.2)	(51.9)	—	45.0
	Ph.D.	—	—	43.9	48.0	54.8	65.0	68.2	68.7	69.0	(65.6)	56.4
Physical chemistry	B.S.	—	—	—	—	—	—	—	—	—	—	46.5
	M.S.	—	—	—	—	—	—	—	—	—	—	55.2
	Ph.D.	—	—	(45.3)	51.0	58.0	61.6	60.0	63.0	(74.5)	(78.4)	59.3
Polymer chemistry	B.S.	—	30.0	32.0	40.0	50.5	48.0	(58.4)	(60.7)	60.0	—	42.0
	M.S.	—	—	35.9	(45.0)	46.6	(58.5)	57.5	(65.6)	(50.0)	(57.2)	47.2
	Ph.D.	—	—	44.6	48.1	56.0	66.0	68.7	66.1	71.0	74.0	60.0

Note: Where no salary data are shown, sample is too small to provide a meaningful figure; data in parentheses are from relatively small samples, as well, and should be viewed with caution. a As of March 1, 1989. b Includes development and design. c Includes quality control. d Includes purchasing, technical service, and economic evaluation. **Source:** ACS survey

For the third straight year, unemployment continues to be very low for chemists

Employment status[a]	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979
Employed full time	95.3%	95.4%	95.4%	94.8%	95.2%	93.7%	93.5%	94.9%	95.6%	95.9%	95.0%
Employed part time	1.5	1.6	1.5	1.5	1.5	1.7	1.7	1.4	1.1	1.0	2.0
Postdoctoral or fellowship	2.2	2.0	2.0	2.0	1.9	2.9	2.6	2.2	2.2	2.2	1.9
Unemployed	1.0	1.0	1.1	1.7	1.4	1.7	2.2	1.5	1.1	0.9	1.1

a As of March 1, 1989; excludes chemists who are not employed but not seeking employment. **Source:** ACS survey

vey, for example, report they also received a bonus last year. As would be expected, the largest bonuses go to managers, with the median being $9000 for chemists working in general management functions ($12,000 for those with a Ph.D.) and $8000 for those in R&D management. For chemists in marketing who received a bonus, the median is $5000. Bonuses generally are lower for chemists in research or other functions.

Academic chemists, as well, can supplement their professional income—with consulting fees, earnings from a second job, summer teaching, and the like. This is especially true for professors working on nine- or 10-month contracts (which is what the majority of them have) rather than 11- or 12-month contracts. Thus the median total income last year for full professors with nine- or 10-month contracts, the ACS survey indicates, was $54,000, although their current annual base salary is $48,000; the median total income for those with 11- or 12-month contracts was $70,000, $67,000 of which came from their base salary. The median amount of supplemental income for associate professors with nine- or 10-month contracts was $4400, for assistant professors $4600.

Professors employed by public schools earn more supplemental income than those at private schools, the survey indicates. And such income is considerably greater for professors at universities that have Ph.D. programs than for those at schools that do not. It also is greater, not surprisingly, for professors who devote more of their time to research than to teaching.

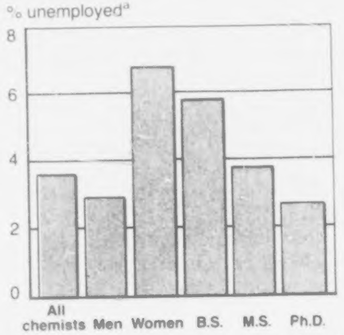
Although just 1.0% of chemists surveyed were unemployed and looking for work last March, 3.6% of the respondents report they were jobless sometime during 1988. The length of unemployment for those out of work generally was not long, though. About 60% report that they were without a job for less than four months; only 16% were unemployed for more than six months.

Unemployment is low whatever chemists do

	% of chemists in category	% unemployed[a]
MOST RECENT EMPLOYER		
Industry	58%	1.0%
Academic	24	0.8
Government	10	0.4
Other	8	2.5
MOST RECENT WORK FUNCTION		
R&D	43%	0.7%
Teaching	12	0.6
R&D management	12	0.4
General management	9	1.7
Marketing[b]	7	1.8
Production[c]	5	1.1
Other	12	2.1
MOST RECENT WORK SPECIALTY		
Analytical	20%	0.9%
Organic	14	1.1
Polymer	11	0.9
Biochemistry	9	0.6
Environmental	8	1.8
Physical	7	0.8
Medicinal[d]	8	0.5
Inorganic	5	0.8
Agricultural and food	4	0.7
Other chemistry	14	1.1

a As of March 1, 1989; excludes chemists who are not employed but not seeking employment. b Includes purchasing, technical service, and economic evaluation. c Includes quality control. d Includes pharmaceutical and clinical chemistry. **Source:** ACS survey

Fewer than 4% of chemists jobless anytime in 1988



a Excludes chemists who were not employed but not seeking employment. **Source:** ACS survey

Most chemists unemployed last year had work within few months

Months unemployed during 1988	Less than 1	1 to 3	4 to 6	7 to 12
All chemists	12%	48%	24%	16%
Men	12	47	27	15
Women	13	56	21	10
Highest degree				
B.S.	15	56	20	9
M.S.	7	52	27	14
Ph.D.	12	45	26	17

Note: Excludes chemists not in the labor force March 1, 1989. **Source:** ACS survey

These statistics on the current economic status of chemists are based on nearly 12,000 responses to a mail survey of a random sample of ACS members undertaken earlier this year by the ACS Market & Business Analysis Department for the Member & Professional Services Department. The survey was limited to members with U.S. mailing addresses who are not students, retired, or emeritus members and who are not over the age of 70.

A considerably more detailed report on the survey is available in the publication "Salaries 1989," which can be purchased from the ACS Distribution Office, Room 210, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036. The price of this year's report is $150. Questions or comments regarding the survey can be directed to Joan Burrelli at ACS headquarters, (202) 872-4433. ☐

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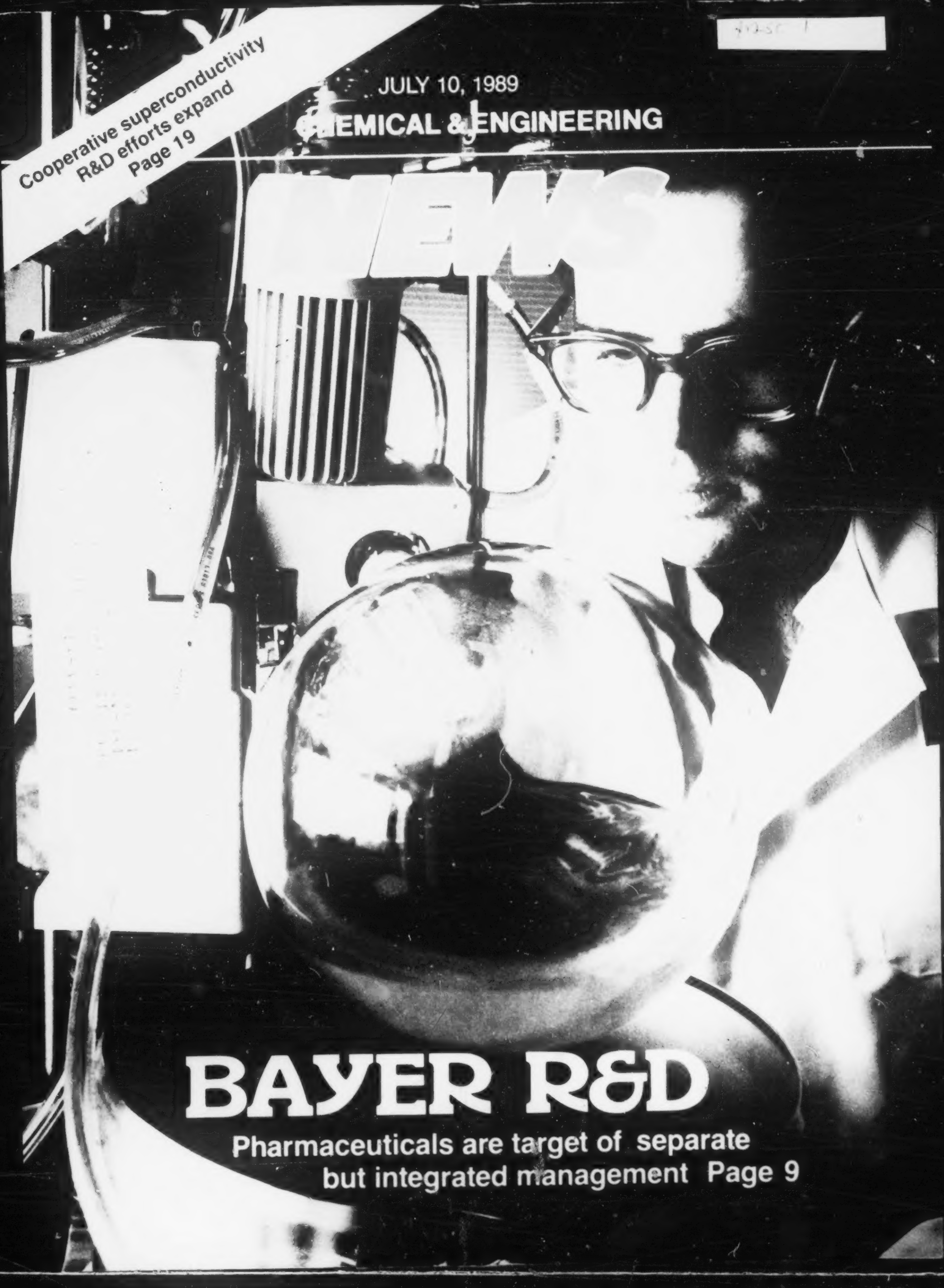
JULY 10, 1989
CHEMICAL & ENGINEERING
NEWS

Cooperative superconductivity R&D efforts expand Page 19



BAYER R&D

Pharmaceuticals are target of separate but integrated management Page 9

CHEMICAL & ENGINEERING
NEWS

Volume 67, Number 28
CENEAR 67 (28) 1–48
ISSN 0009-2347

JULY 10, 1989

News of the Week

- **Indian Supreme Court to hear challenges this week to Bhopal settlement.** Page 4
- **Ethylene prices will remain stable, despite declines forecast, as a result of planned, accidental plant shutdowns.** Page 5
- **General Electric and the University of Utah agree to joint effort to study, develop cold fusion phenomenon.** Page 5
- **Revlon joins four other cosmetic firms in halting use of animals for product testing.** Page 6
- **West German chemical industry concerned over chemical trade of Düsseldorf-based firm with Iran; 75 Senators write President, offer to support his efforts to negotiate chemical weapons treaty.** Page 6
- **French state-owned Orkem and Enimont, the Italian chemicals firm, agree to exchange operations of select chemical plants.** Page 6

Business

U.S. chemical trade with communist countries is up sharply, with exports to these nations increasing a whopping 50% in 1988 to $1.73 billion. **Page 12**

Government

As military services continue to struggle to comply with nation's toxic waste laws, Council on Environmental Quality reports much success, but President and Congress look for greater progress. **Page 15**

General Accounting Office finds OSHA's contractor use and spending at acceptable levels. **Page 16**

Science/Technology

Commercial promise of high-temperature superconductors triggers cooperative R&D efforts among corporations, universities, and government labs. **Page 19**

Restructuring of Soviet industry's R&D-to-production mechanisms is falling behind, according to Department of Defense report. **Page 22**

Education

Summer program at Indiana college offers selected high school students hands-on approach to all aspects of engineering. **Page 25**

People

George C. Pimentel is remembered by friends and colleagues as a man devoted to chemistry and to education. **Page 27**

Cover: Miles researcher works with molecular biology project

Letters 2
Concentrates
Business 7
Government 14
Science/Technology 18
The Departments
ACS Comment 31
ACS News 32
Newscripts 48

Cover Story

West Germany's Bayer is going global in pharmaceutical research, expanding its research center in the U.S. and moving ahead with plans for a similar center in Japan. Page 9

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LETTERS

Scientific literacy

SIR: I endorse the letter from Ephraim Banks (C&EN, May 22, page 2) regarding scientific literacy. I agree that the grade school teacher population is the major one to approach for the interest level, and the [grade school] portion of the curriculum is the one that needs stimulus.

When young children are stimulated and find something interesting and/or fun they usually continue to pursue it. Therefore, the earlier that one starts to do this the more likely the ultimate benefit.

At the present time we are, unfortunately, looking at something that may take 10 to 15 years to reverse, because the current school systems are reasonably embedded in technique rituals that do take time to modify usefully.

H. William Gillen
Clinical Professor, Neurology
University of North Carolina, Wilmington

Health and environment

SIR: No reasonable person can doubt the need for rigorous science in considerations of health and the environment. But sometimes the appeal for such rigor has been misused so transparently, it understandably leads to skepticism as to the honesty of some industries and their spokesmen, who flout what should be the motivating idea of prudent persons: When important health or environmental issues are at stake, assume the worst even in the absence of definitive studies.

To be sure, economically costly mistakes may sometimes be made. (Has that ever occurred?) But the alternative is, ultimately, to take the cynic's point of view, which one such person expressed to me as, "I don't care what happens after I die." Indeed, the list of major issues, most of which have been resolved on the side of prudence, is almost frighteningly long: the effect of smoking on health and longevity, the destruction of the ozone layer by CFCs, the hazards of pesticides, the influence of phosphates on eutrophication, toxic landfills such as Love Canal, the effect of agent orange on those exposed to it, the health consequences of intrauterine devices, the safety of certain topical antimicrobials, the safety of nuclear reactors, and on and on.

In every instance, the immediate posture taken by industry was to deny the allegations of harm. I surely do not advocate abandoning the requirement of sound epidemiological studies. But I do advocate, when good epidemiological data are unavailable and there is good reason to question safety, that society take the most conservative view: Health and the environment must take precedence over profit. To do otherwise is not merely to betray whatever trust laymen still place in science, but often to condemn the innocent to injury and even death. It is, by now, commonplace that lay persons rely less and less on the assurances given them by scientists. Is it any wonder, given the magnitude and seriousness of the problems cited above, that science is suffering what can appropriately be called a credibility gap?

By automatically advocating the positions taken by their industries in questions of social concern, positions that almost always deride accusatory evidence about the safety of products or operations, some industrial scientists have abrogated the charge invested in them by their training and presumed dedication: Be fair to all the facts. To compel the innocent to suffer the possible hazardous consequences of what all too often are no more than guesses as to presumed safety is not merely arrogant, but possibly criminal.

David Taber
Chicago

Laboratory organic chemistry

SIR: The Science/Technology section reports on the new developments in the teaching of laboratory organic chemistry (C&EN, May 8, page 32). The movement to microscale is undergoing rapid growth and wide acceptance throughout the academic community. Kenneth Williamson's text attempts to bridge the gap between those who require some macro techniques, but want to introduce a significant number of micro experiments to their students.

The article gave credit to the role of Ace Glass and Kontes for producing specialized microscale glassware, but failed to mention that Pfaltz & Bauer Inc. has been endorsed by Dana Mayo as well as by Williamson to prepare chemicals in kit form for all the microscale experiments in their texts.

The kits are prepared in sets for 10, 20, and 30 students, with a 30% excess. All

Correction

• June 26, page 35: In box, the Program for Alternative Fluorocarbon Toxicity Testing's third effort, PAFTT III, will examine HCFC-124 (C_2HClF_4) and HFC-125 (C_2HF_5), not CFC-115 and HCFC-22.

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Chemical trade with communist nations climbs

Chemicals have become an important part of U.S. exports to communist countries. The converse, however, is a different story. Still, exports to communist countries play only a minor role in the overall U.S. chemical export picture.

U.S. chemical exports, for instance, have accounted for an average 10% of total U.S. exports over the past few years. Last year, when chemical exports hit a record $32.3 billion, they amounted to 11% of all U.S. exports.

However, when the markets are communist countries, chemicals account for a hefty 20% of U.S. exports. Chemicals, in fact, are the third largest product category that the U.S. ships to communist customers, exceeded only by food and machinery and transport equipment.

According to a recent study by the International Trade Commission, U.S. chemical exports to communist nations increased a whopping 50% in 1988 over 1987 to $1.73 billion. That growth rate is almost twice that for total chemical exports.

Despite these impressive numbers, communist countries take a relatively small, but growing, slice of all the chemicals that the U.S. exports. In 1988, communist countries accounted for only 5.4% of total U.S. chemical exports, up from 4.4% in 1987.

In terms of chemical imports, trade with communist countries is almost nonexistent. Although chemical imports from these countries increased 25% last year, they still accounted for only 4% of total shipments from communist countries. And, at only $447 million, they represented a paltry 2.3% of all chemicals imported into the U.S. in 1988.

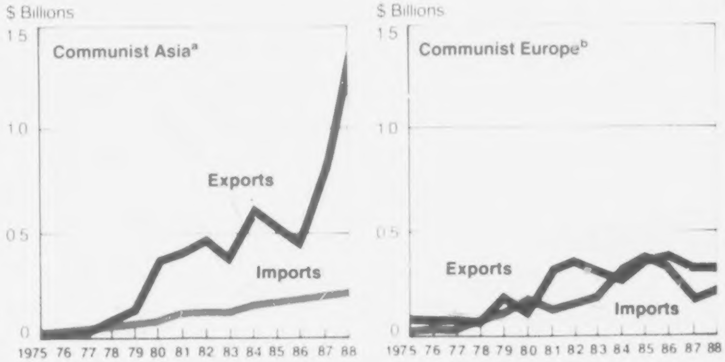
The result is a lopsided chemical trade surplus for the U.S. with communist nations. Last year that surplus swelled to $1.3 billion, up substantially from $799 million in 1987. In 1986, the chemical trade surplus with these communist countries was only $330 million.

Over the past few years, China has emerged as the leading communist trading partner with the U.S. China alone buys almost 58% of total U.S. exports to communist countries and 80% of the chemical exports. Trade with the Soviet Union pales by comparison, with 32% of total exports and 16% of chemical exports.

China is also the leader on the import side of the ledger. It accounts for almost 80% of total U.S. imports from communist countries and for more than half of all chemical imports from communist sources.

Last year, U.S. chemical exports to China increased 72% from 1987 to $1.4 billion. That represents a surprising 28% of all U.S. exports to that country. Two products alone—fertilizer and polypropylene—ac-

U.S. chemical trade with communist Asia grows faster, is much larger than with communist Europe



a Includes China b Includes U.S.S.R. Sources: [illegible] counted for almost half of those chemical exports. In an attempt to boost its own grain output, which remained well below the record 1984 harvest, China increased its imports of U.S. fertilizer last year 40% to $379 million.

U.S. plastics and resins exports to China soared 134% last year to $595 million. This huge increase reflects China's growing demand for plastics and resins in the agricultural sector (particularly sheeting) and industry. The country imported $301 million of polypropylene, $64 million of low-density polyethylene, $55 million of acrylonitrile-butadiene-styrene resins, and $51 million of high-density polyethylene.

U.S. organic chemicals also figured heavily on China's shopping list. Its imports of these materials from the U.S. increased 71% last year to $256 million. Largest export item in this category: carboxylic acids, anhydrides, and their derivatives.

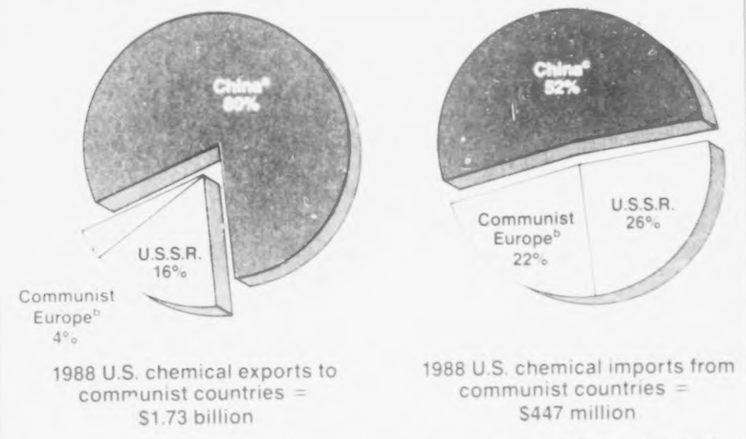
Compared with China, the Soviet Union is a relatively small customer for U.S. chemical exports. Last year, those exports amounted to only $273 million and represented only 10% of total U.S. exports to the U.S.S.R. The big-ticket items among U.S. shipments to the U.S.S.R., as usual, were grains—corn, wheat, soybeans—as well as soybean oil cake and meal. Of the $273 million in chemicals exported to the Soviet Union last year, almost 82% was fertilizer. The only other chemical export of any significance was $12 million worth of catalyst preparations.

U.S. imports from the U.S.S.R. hit $563 million last year, but most of that was petroleum and petroleum products. Chemical imports were only $116 million. Still, that amounts to 21% of total imports from the U.S.S.R. Three products account for the bulk of the Soviet Union's chemical shipments to the U.S. By far the largest is anhydrous ammonia ($63 million in 1988), followed by crude potassium chloride ($24 million) and uranium compounds ($9 million).

Aside from China, U.S. chemical trade with communist Asia is virtually nonexistent. But the U.S. did export $69 million worth of chemicals to Eastern European nations (excluding the U.S.S.R.) and imported $101 million in chemicals. This means that Eastern Europe is the only communist area that enjoys a chemical trade surplus with the U.S.

Of the Soviet-aligned European countries, Poland overshadows all others as a market for U.S. chemicals. It bought $32 million worth last year, 46% of the total for Eastern Europe (excluding the U.S.S.R.). Poland also accounts for 30% of the chemicals that the U.S. imports from Eastern Europe.

Earl Anderson



China leads communist nations in chemical trade with U.S.

1988 U.S. chemical exports to communist countries = $1.73 billion

1988 U.S. chemical imports from communist countries = $447 million

a U.S. chemical exports to rest of communist Asia in 1988 amounted to only about $1 million. b Excludes U.S.S.R. c U.S. chemical imports from rest of communist Asia in 1988 were negligible. **Source**: International Trade Commission.

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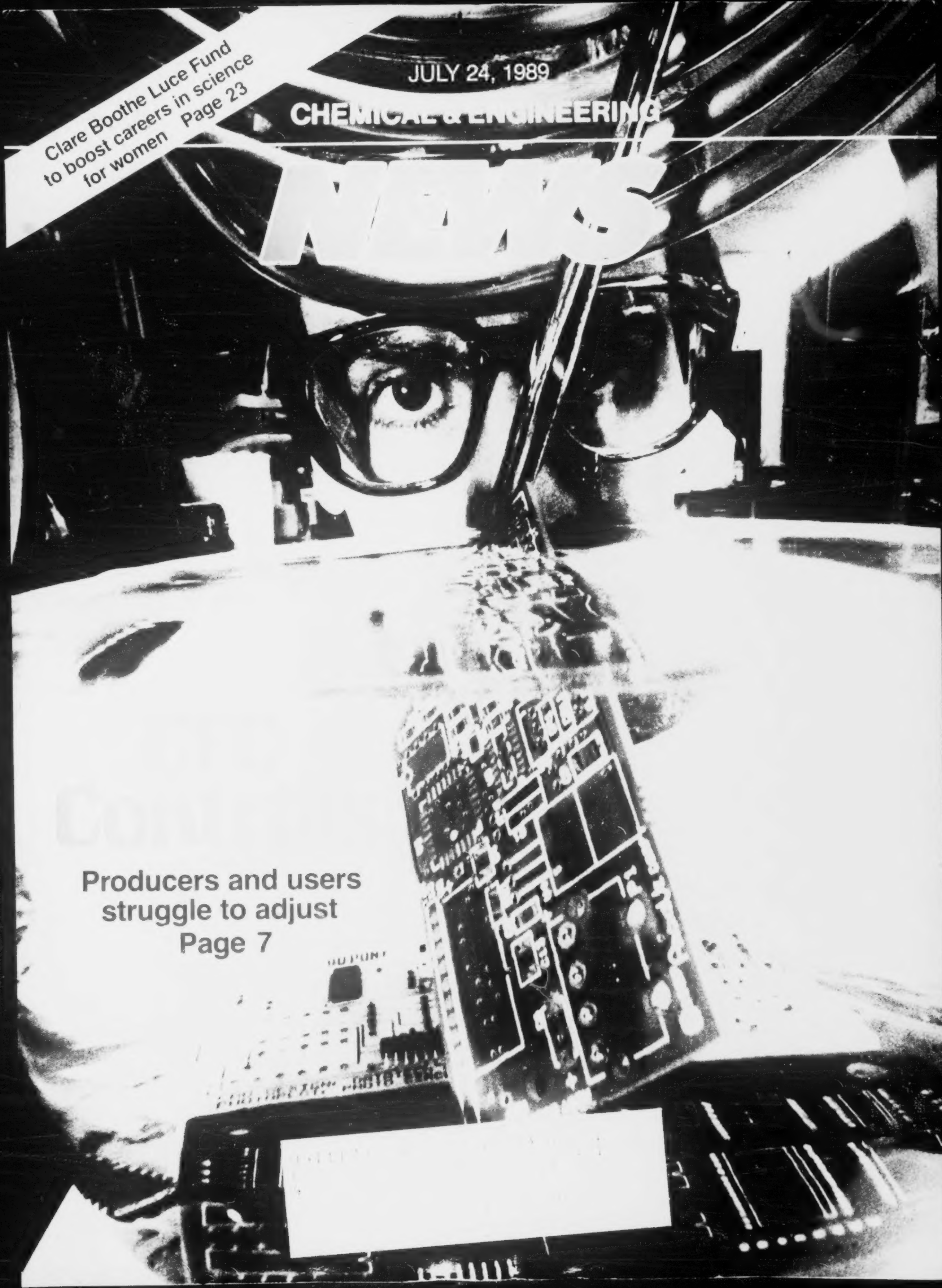
CHEMICAL & ENGINEERING

NEWS

Clare Boothe Luce Fund
to boost careers in science
for women Page 23



Producers and users
struggle to adjust
Page 7

CHEMICAL & ENGINEERING NEWS

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JULY 24, 1989

News of the Week

- **Speaking at celebration of 20th anniversary of first manned landing on the moon, President Bush endorses space station, manned moon base, and manned Mars mission.** Page 4
- **Negotiators for the U.S. and the Soviet Union take positive but limited steps toward achieving a ban on chemical weapons.** Page 5
- **European Community's science attaché discusses the EC's plans for R&D and its protectionist policies as the EC prepares to drop trade barriers in 1992.** Page 5
- **Marion Laboratories, Merrell Dow Pharmaceuticals to merge, forming one of the world's 15 largest drug firms.** Page 6
- **Drug candidates for AIDS nearly double in two years, with 67 medicines and vaccines currently in human clinical trials.** Page 6
- **Union Carbide's Frederick Bailey and Wayne State University's Stanley Kirschner are petition candidates for ACS Board of Directors election this fall.** Page 6

Letters 2
Editor's Page 3

Concentrates
Business 14
Government 19
Science/Technology 22

The Department
Newscripts 44

Business

Chemical specialties are becoming significant part of the operations of European detergents and food products giant Unilever. **Page 16**

Government

Legislation to ensure safety of hazardous materials transportation and to boost funding for training local emergency response teams is goal of House subcommittee hearings. **Page 20**

Education

Clare Boothe Luce Fund provides assistance to women pursuing careers in "hard" sciences and engineering. **Page 23**

U.S. team earns 14th place at International Chemistry Olympiad held in Halle, East Germany. **Page 25**

Science/Technology

West Germany's BASF centralizes environmental monitoring for its Ludwigshafen chemical complex. **Page 26**

Paper, pulp mill wastes have low levels of dioxin, according to industry-government study. **Page 28**

New FTIR instruments offered by Perkin-Elmer cover separate spectral regions. **Page 28**

Books

"The Path of No Resistance" tells superconductivity story well, but in broad terms, lacks technical detail. **Page 29**

News Focus

Producers and users grapple with harsh realities of CFCs phaseout, with first cap on production of fully halogenated compounds in effect since July 1, phaseout timetable still being debated, U.S. producers facing a possible windfall profits tax, and state and local regulations proliferating. **Page 7**

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LETTERS

CHEMICAL SAFETY

Iodosobenzene salt explosion

SIR: Iodosobenzene tetrafluoroborate was described in 1988 by V. V. Zhdankin et al. [*Tetrahedron Lett.*, **29**, 3717 (1988)] as the first stable hypervalent iodine reagent without a nucleophilic ligand. After having prepared a few grams of the product according to the protocol in the cited literature without any difficulties, we decided to undertake a 0.5 mol preparation in the same manner. After drying the yellow crude product (about 75 g) in vacuo at room temperature for about 20 hours, it exploded while still in the flask in vacuo, producing a considerable amount of pungent fumes. The blast from the explosion was such that fragments of the flask penetrated glassware standing nearby as well as a security shield located in front of the flask. Fortunately, no one was in the laboratory at the time of the explosion.

We are unable to say whether the explosion was caused by impurities or by the instability of the product itself. However we would like to warn anyone preparing or handling iodosobenzene tetrafluoroborate to be extremely careful.

Gert van Look
Fluka Chemie A.G.
Buchs, Switzerland

Public image problem

SIR: The chemical industry has a public image problem nearly as serious as that of the nuclear power industry. Both industries produce harmful by-products (and in some cases, products) that are not always disposed of safely. An unwitting public has occasionally been exposed to dangerous levels of toxic wastes. This has tended to erode public trust in the industry and its spokesmen.

Unfortunately, the response of the chemical industry in general, and C&EN writers in particular, has often been a defensive, reflexive denial of the problem. To be sure, apocalyptic environmentalists are sometimes just as guilty of this unthinking, knee-jerk approach to chemistry (and science in general). But this is all the more reason to approach these problems rationally, admitting fault and proposing effective, timely solutions where appropriate. Here are two examples.

The first is John Weisburger's review of "In Search of Safety: Chemicals and Cancer Risk," by John Graham et al. (C&EN, May 22, page 35). For a page and a half Weisburger gives a lucid review of a well-written book analyzing the scientific, legal, and public policy aspects of regulating exposure to carcinogens. At the very end of the piece he adds his own personal opinion that since lifestyle factors (primarily smoking and nutrition) are responsible for 65 to 90% of cancer cases, the fight against cancer would be more effectively waged on the educational front (to alter lifestyles) than on the regulatory front. This pro-industry sentiment is prominently featured by the editors at the head of the article, even though it is presented as Weisburger's own opinion and not that of the authors of the reviewed book. I might add here that we are not forced to choose between education or regulation: We can and should do both. Lifestyle is voluntary, however, and cannot be regulated in a free society. Chemical exposure, which by Weisburger's lowest estimate causes 100,000 cancer cases annually, can and must be legally regulated.

Robert Hollingworth's review of "Pesticide Alert" by Laurie Mott and Karen Snyder (C&EN, May 8, page 35) was even more biased and self-serving. He marshals three arguments to support his contention that the dangers of pesticides are minimal and are far outweighed by their benefits. (1) "For almost every pesticide, the dietary intake is less than 1% of the acceptable daily intake defined by toxicologists." I have two problems here: One is the "almost" (what of the others); and second, Hol-

Correction

- June 19, page 98: In the Committee on Professional Training table, the data for chemistry graduates from the University of Washington and Wayne State University were transposed. Therefore, the tables on page 99 should have Washington as 17th in the ranking of producers of bachelor graduates, with 50, and Wayne State as 23rd, with 45. For certified bachelor graduates, Washington, not Wayne State, ranked seventh with 37. For masters graduates, Washington ranked eighth with 17, and Wayne State 20th with 14. For Ph.D.s, Washington, not Wayne State, ranked 25th with 22. Also, Washington, not Wayne State, was the only school apart from the University of Illinois, Urbana-Champaign, to appear in all four rankings.

NEWS FOCUS

Producers, Users Grapple with Realities of CFC Phaseout

First cap on chlorofluorocarbon production went into effect on July 1, with timetable for phaseout still being debated, U.S. producers facing possible windfall profits tax, and state and local regulations proliferating

Pamela S. Zurer, C&EN Washington

For the chlorofluorocarbon (CFC) industry, nothing is certain these days but death and taxes. The business of producing CFCs is doomed—the only question is how quickly the end will come. And the Bush Administration is determined to impose a windfall profits tax on the makers of CFCs as production of the chemicals is cut back.

But surrounding those harsh realities are many uncertainties. The timetable for phasing out the ozone-depleting chemicals is still being debated, both in the international arena and among U.S. policymakers. Within the U.S., state governments are adding their own restrictions to those already imposed by the federal Environmental Protection Agency (EPA).

The chemicals, processes, and technologies that will replace CFCs in their myriad uses are still being identified. One of the industries that uses CFCs, rigid foam insulation, fears for its life. Many others, ranging from the electronics industry to automobile manufacturing, are shaken by the need to forego CFCs. And the most likely chemical substitutes—chlorofluorocarbons that bear hydrogen atoms (HCFCs)—may themselves end up being regulated as potential ozone depleters.

On July 1, the first restrictions on the manufacture of fully halogenated CFCs went into effect. Producers were required to freeze their output of the chemicals at 1986 levels. That production cap—required under the terms of the Montreal Protocol on Substances That Deplete the Ozone Layer and by EPA regulations that implement that international treaty within the U.S.—is turning out to be a production cut of 15% or more, because output of CFCs has grown since 1986.

As they now stand, the Montreal protocol and EPA rules require that CFC production be reduced another 20% by mid-1993, then an additional 30% by mid-1998. Output of halons (fluorocarbons that contain bromine) is to be frozen at 1986 levels in 1992. EPA has set up a quota system that allocates future production of the controlled chemicals based on each U.S. producer's share of the 1986 market for halons.

Recycling of CFC-12 from automobile air conditioners could become mandatory under pending legislation

But the Montreal protocol was out of date even before it went into effect. Since it was negotiated in 1987, a flood of scientific data has indicated the treaty as currently written will not adequately protect the ozone layer from chlorine-catalyzed destruction. In the past two years the atmospheric science community has made three major findings:

- Chlorine and bromine from CFCs and halons are a primary factor in the seasonal loss of ozone at the South Pole known as the Antarctic "ozone hole"

C&EN staff photos

Claussen (left): too fast a phaseout has a downside. McCain (center): the idea is to have an orderly transition. Fay: industry knows it has to get out of CFCs

(C&EN, May 30, 1988, page 16). In the worst year to date, 1987, 50% of the ozone over Antarctica was destroyed during September and October.

- On a global basis, the ozone layer has shrunk an average of about 2.5% during the past decade, even after accounting for natural variability (C&EN, March 21, 1988, page 6).
- The winter atmosphere in the north polar region is loaded with the same destructive chlorine compounds that cause the Antarctic ozone hole. Although no massive loss of ozone has been observed in the Arctic, scientists participating in an international research program that probed the Arctic stratosphere last winter concluded the potential for significant change is there (C&EN, March 6, page 29).

The accumulation of bad news about the layer of ozone that protects Earth's surface from harmful ultraviolet (UV) radiation has led to a consensus that tighter controls on chemicals that carry halogen atoms into the stratosphere are necessary. If provisions set in the Montreal protocol were to be followed, chlorine concentrations would continue to increase for more than a century. Stricter controls on halogenated compounds are required simply to stabilize the chlorine content of the atmosphere at today's levels of about 3 ppb, much less reduce them below the concentrations—about 2.7 ppb—that existed when the Antarctic ozone hole was first identified in 1985.

Given the reality of the science, over the past 18 months industrial producers and users of CFCs—led by Du Pont, the company that makes about 25% of CFCs produced worldwide and dominates the U.S. market—have joined environmental groups, scientists, and politicians calling for a phaseout of CFCs.

"When the industry decided in 1986 to support an international agreement to limit the use of CFCs, it recognized that the long-term life of the current compounds was going to be limited," says Kevin J. Fay, executive director of the Alliance for Responsible CFC Policy. That industry group is a coalition of all five domestic CFC manufacturers and several hundred businesses that use CFCs.

"Now, based on science and the political climate of today, it's clear they are going to be a lot more limited than we thought the science justified in 1986," Fay says. "Back then it appeared that you only had to cap the growth in use of the compounds. I don't think anybody believes that anymore. Even under the Montreal protocol, you get substantial increases in chlorine concentrations in the atmosphere."

But the Montreal protocol soon will be strengthened. In Helsinki in early May, delegates to the first meeting of the countries that have joined the treaty agreed on their intention to phase out production and consumption of CFCs no later than the year 2000. They also agreed to eliminate halons and control other ozone-depleting substances like carbon tetrachloride (CCl_4) and methyl chloroform (CH_3CCl_3) as soon as feasible (C&EN, June 26, page 33).

Four review panels set up by the United Nations Environment Program (UNEP) are now completing scientific, environmental, technical, and economic assessments of the issues surrounding these tighter controls. Once UNEP has received their reports, amendments to the Montreal protocol will be drafted this fall. A CFC phaseout is expected to be formally adopted next spring when the parties meet again to renegotiate the treaty.

However, although an eventual phaseout of CFCs now appears inevitable, the timing of their elimination is still being negotiated. The year 2000 is too late, according to some environmentalists and politicians. The most extreme position is that taken by Greenpeace, an international environmental group, which is calling for an immediate ban on all production and consumption of CFCs and halons. Others, while conceding the need for some transition time, argue the phaseout must be speeded up. A new bill in the Senate, for example, calls for their elimination within five years.

"The 2000 date is not acceptable in our view," says Liz Cook, project director for the Friends of the Earth Foundation's (FOE's) ozone campaign. "That schedule is based on a timetable the chemical industry has set for itself. It doesn't force technological innovation."

Some Scandanavian countries have already committed themselves to phaseouts before 2000, Cook points out. Others, including the European Community, have pledged to cut CFC output 85% as soon as possible.

"The idea is to have an orderly transition over the next decade or so," argues C. Anthony McCain, program manager of Du Pont's Freon products division. "There will be immediate injuries to people if we move too fast, because they will not choose the best solutions. They'll be exposed to toxic, flammable materials."

EPA agrees that 2000 is soon enough. "Although some people have said they would like a phaseout faster than 2000, we don't believe there is much environmental benefit to doing it faster and there is a downside," says Eileen B. Claussen, director of the agency's office of atmospheric and indoor air programs. "You might pick poorer alternatives because they are available first."

The fate of halons is also uncertain. Although output of halons is small compared with CFCs, bromine derived from those compounds is even more destructive to stratospheric ozone than chlorine. The U.S. and some other countries have called for an international phaseout of halons by 2000, but the extent and timing of further controls remains to be negotiated.

Carbon tetrachloride and methyl chloroform are also in limbo. EPA argued forcefully at the Helsinki meeting that both could be significant future sources of chlorine in the stratosphere if their output is allowed to grow unchecked.

Carbon tetrachloride is used primarily as a chemical intermediate in the U.S., but Soviet bloc and developing countries use it in ways that allow emissions to the atmosphere, according to Claussen. As for methyl chloroform, EPA fears that manufacturers will use it as a substitute for other solvents—primarily CFC-113 ($C_2Cl_3F_3$)—that have been restricted.

"I am sure that both carbon tet and methyl chloroform will end up in the renegotiation" of the Montreal protocol, Claussen says. "But whether they end up at a freeze or some reduction I don't know yet. Technically, if you want to stabilize chlorine in the atmosphere—which is not necessarily a wonderful environmental goal—you probably have to do away with both of them over some period of time."

Meanwhile, prices of CFCs have already begun to rise as the supply shrinks under the current restrictions—from about 60 and 70 cents per lb for CFC-11 (CCl_3F) and CFC-12 (CCl_2F_2) a year ago to approximately 80 and 90 cents per lb today. EPA estimates prices may eventually rise as much as fivefold, bringing producers several billion extra dollars, depending on how fast users switch to substitute products or alternative technologies.

"The government is restricting the supply of CFCs for a good environmental reason," says attorney David D. Doniger, director of the Natural Resources Defense Council's ozone protection project. "The effect is the same as the OPEC cartel's oil restrictions' effect on oil prices. If the price goes up but the production costs don't, that's pure windfall profit."

Almost a year ago, EPA floated the idea of imposing a regulatory fee on CFC producers or an auction system to recoup those additional revenues. Otherwise, the agency suggested, CFC producers might lack the incentive to come up with substitutes.

EPA still has not taken any action. But the Bush Administration has included $400 million in CFC windfall profits revenue in its proposed fiscal 1990 federal budget and is projecting another $1.4 billion for the following year—much to the fury of CFC producers.

"This is definitely inappropriate," says Anthony Vogelsberg, environmental manager of Du Pont's Freon products division. "The scheme would extract the very revenues necessary to do the research and development work necessary to replace CFCs."

Such a tax would also place U.S. companies at a competitive disadvantage, argues William Corcoran, director of public affairs for Allied-Signal, the second largest U.S. CFC producer. "The American companies are doing a good job with moving ahead with alternatives," he says. "Now we'll be hit with a big tax—which no other country imposes—that makes it tougher for us to maintain our lead."

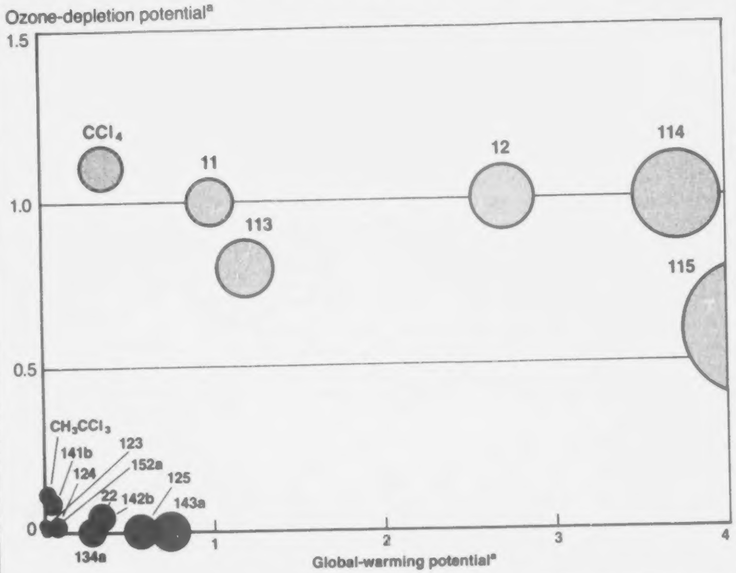
However, that view hasn't garnered a lot of sympa-

Eight halocarbons are controlled under Montreal protocol

Substance	Ozone-depletion potential[a]	Atmospheric lifetime, years	Major uses
GROUP 1—Production cuts mandated			
CCl_3F (CFC-11)	1.0	75	Flexible foam, rigid polyurethane foam, refrigeration, air-conditioning
CCl_2F_2 (CFC-12)	1.0	111	Rigid polyurethane and rigid nonpolyurethane foam, refrigeration, air-conditioning, aerosols, sterilization, food-freezing
$C_2Cl_3F_3$ (CFC-113)	0.8	90	Solvent
$C_2Cl_2F_4$ (CFC-114)	1.0	185	Rigid nonurethane foam, refrigeration, air-conditioning
C_2ClF_5 (CFC-115)	0.6	380	Refrigeration, air-conditioning
GROUP 2—Production freeze mandated			
$CBrClF_2$ (Halon-1211)	3.0	25	Portable fire extinguishers
$CBrF_3$ (Halon-1301)	10.0	110	Total flooding fire-extinguishing systems
$C_2Br_2F_4$ (Halon-2402)	6.0	na	Fire extinguishers

[a] Estimates depending on chlorine and bromine content and atmospheric lifetime. Potentials are set relative to CFC-11, which is assigned a value of 1.0. **na** = not available. **Source:** Environmental Protection Agency

Potential CFC substitutes pose less risk to ozone, climate



Note: Area of circles is proportional to each compound's atmospheric lifetime. Yellow circles represent fully halogenated CFCs and carbon tetrachloride. Blue circles represent HCFCs and methyl chloroform. Green circles represent HFCs, which contain no chlorine. a Calculated potentials set relative to CFC-11, which is assigned a value of 1.0. **Source:** Du Pont

thy in some quarters. "There are no entities who deserve the windfall less than the CFC producers that stonewalled this issue for so long and got us into this mess," NRDC's Doniger says. "So we are in favor of the windfall profits mechanism to take those profits away. We're encouraged by EPA's discussion and even more encouraged by the Bush Administration's inclusion of the money in the budget."

Congress, not EPA, looks likely to make the final decision on the issue. Although EPA is careful to refer to potential CFC windfall revenues as "fees," they bear a strong resemblance to taxes—which only Congress can impose. The Justice Department says EPA has the authority to implement a fee or auction system under the Clean Air Act. But the General Accounting Office noted in the recent study that EPA will undoubtedly be sued if it does.

But it probably won't come to a lawsuit. The Senate Environment & Public Works Committee has embraced CFC taxes as a way to come up with most of the $450 million it has orders to slash from the fiscal 1990 budget. The committee is leaning toward a tax on each pound of CFCs and halons produced, with the amount increasing each year until the compounds are phased out.

Although the final budget won't be enacted until fall, CFC producers are facing the likely reality of having to pay a windfall profits tax. "In order to get that money we would have to triple the prices of CFCs next year," Du Pont's McCain says bluntly. "If we have to pay that money we will pass that cost on to the user. He'll pay for it and we'll pass it on to the government for him. Some users will go out of business."

The CFC users that will suffer the most as supplies become short and prices rise are makers of rigid insulating foam. CFC-11 is used to blow the polyurethane and polyisocyanate foam insulation widely used in new construction and remodeling. The CFCs not only mechanically expand the foams, but are trapped within them, contributing to their insulating capacity.

The foams already face stiff competition from other types of insulation, such as glass fiber, notes Stephen O. Anderson, chief of EPA's technology and economics branch in the division of global change. "They face a fragile market because there are so many other good alternatives," he says.

The foam insulation industry is evaluating HCFCs-123 ($CHCl_2CF_3$) and -141b (CH_3CCl_2F) as substitutes for CFC-11. But these compounds are still undergoing long-term toxicity testing and process development and are not yet available in commercial quantities. Du Pont recently announced plans to build a commercial-scale plant for HCFC-123 in Maitland, Ontario, but it won't be able to sell any until 1991 at the earliest, and then only if everything goes right. "We're taking a significant financial risk to try to get material out to our customers," McCain says.

In any case, the HCFCs will cost several times what CFCs now cost—perhaps too expensive for foams to compete with other types of insulation. If a windfall profits tax is imposed on the current CFCs, the industry argues, foam insulation makers will be out of business that much sooner.

The auto industry is fighting additional restrictions on CFCs on a different front—the state level. In May, the Vermont legislature outlawed the registration of cars with air conditioners that use CFCs beginning with 1993 models. California's lawmakers may soon follow suit. A bill just introduced in the U.S. Senate would make it illegal to sell or export cars that use CFCs in their air conditioners after 1993.

U.S. carmakers say they can't make the 1993 deadline. "We may not have any cars that use the substitutes by the '93 auto year," says General Motors' Gerald F. Stofflet, chairman of the Motor Vehicles Manufacturers Association's CFC subcommittee.

About 90% of the new cars sold in the U.S. have air conditioners. All use CFC-12. Automakers in the U.S., Europe, and Japan are testing new systems that use HFC-134a (CH_2FCF_3), which contains no chlorine atoms. Both Du Pont and ICI are working on commercial-scale plants to produce HFC-134a, which

C&EN staff photos

Doniger (left): a balanced position is available. Anderson: foams face a fragile market

also has potential uses in home and commercial refrigeration. But as is the case with the HCFCs, toxicity tests and process development on HFC-134a won't be completed for several years. Furthermore, as Du Pont's McCain points out, HFC-134a is not a "drop-in" replacement for CFC-12.

"Everybody's working, trying to get HFC-134a in, but there are still many uncertainties," Stofflet says. "We release the 1993 models for tooling at the end of this year and trying to put in a different system after that is a disaster. The earliest we can do it is the 1994 model year."

Even then, Stofflet says, the auto companies will be taking a big risk because they will have to finalize their designs before all testing is complete. And the new air-conditioning systems require so many changes throughout the cars that the companies will not be able to put them in all models at once, he says, but will have to phase them in over three or four years.

The headache that the automakers are facing stems from an outpouring of legislation pending at the state and local level that restrict CFCs. "We're running around putting out fires," Stofflet says. "It's a real problem. Each state proposes something a little bit different."

Not all the proposed legislation involves the auto restrictions that Vermont's does. Instead, most proposed bills are more like one recently enacted in Hawaii, which requires recycling of CFC-12 when auto air conditioners are serviced and bans the sale of small cans of the refrigerant for home use. Other pending bills would require labeling of products that contain or are made with CFCs.

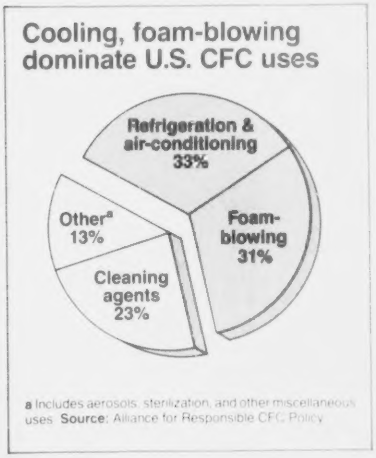
All this legislation—some 90 bills in more than 20 states this spring—is a result of EPA's decision that its federal regulations controlling production of CFCs do not preempt the rights of states and municipalities to enact their own restrictions on the chemicals. CFC producers and users are most unhappy with that decision—and environmental groups are taking full advantage of it.

"It would be disingenuous for me to pretend that we are not aware that it can be inconvenient to companies who want uniform national markets," NRDC's Doniger says. "So our strategy is to promote this state-level action. But I don't want people to think we can turn it on or off. A lot of it is indigenous. The activity reflects real concern at a grass-roots level that the global process and the U.S. federal process are working too slowly."

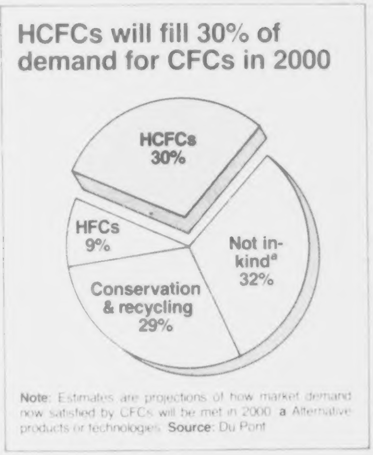
"We don't need these state and local initiatives to persuade the industry that we have to get out of these compounds," Fay says. "We know that. States and localities would be far better off finding where they use CFCs and putting their own ozone protection programs into place rather than trying to ban the registrations of auto air-conditioning systems or banning individual products. That is not going to affect the total amount of CFC use in this country because we are going to be in a shortage situation governed by the Montreal protocol. All these individual efforts to try to ban a product here or a product there are not going to accomplish anything."

But according to environmentalists who have been involved in state initiatives, the goal of the bills is not just to tighten supplies of CFCs. It is to restrict needless emissions and conserve CFCs for essential uses like servicing existing refrigeration equipment.

"We're working with states on banning frivolous uses and on mandatory recycling for auto air-conditioning," FOE's Cook says. She points out that releases of CFC-12 from car and truck air con-



a Includes aerosols, sterilization, and other miscellaneous uses. **Source:** Alliance for Responsible CFC Policy



Note: Estimates are projections of how market demand now satisfied by CFCs will be met in 2000. a Alternative products or technologies. **Source:** Du Pont

Many routes lead to hydrogen-bearing alternatives to CFCs

The very stability of fully halogenated CFCs that makes them so useful is the same characteristic that renders them dangerous to the stratospheric ozone layer. Because they are so unreactive, essentially all CFC molecules that are emitted in the lower atmosphere eventually diffuse into the stratosphere. The intense ultraviolet radiation there liberates chlorine atoms that then can catalyze reactions that destroy ozone molecules.

In contrast, hydrogen atoms on the leading candidates to replace the fully halogenated CFCs—hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs)—make them susceptible to degradation in the lower atmosphere, before they can reach the stratosphere. But those same hydrogen atoms that make the alternative compounds less destructive to ozone make them more difficult and thus more costly to prepare.

C&EN staff photo

Manzer: a chance for a global impact

It's easy to make the fully halogenated compounds. To prepare CFC-11 (CCl_3F) and CFC-12 (CCl_2F_2), carbon tetrachloride (CCl_4) is mixed with hydrogen fluoride (HF) in the presence of a catalyst. The temperature and pressure in the reactor control how many chlorine atoms are exchanged for fluorine: one exchange gives CFC-11; two exchanges CFC-12.

The key to developing alternatives, says Leo E. Manzer, research manager at Du Pont's experimental station in Wilmington, is to match the physical properties of the CFCs being replaced. "There's an estimated $135 billion worth of equipment in the U.S. that uses CFCs," he says. "Clearly you can't ask everybody to scrap their old equipment, then redesign, rebuild, and put in all new equipment. You've got to find something that comes close to the existing compounds."

But to add hydrogen atoms to ensure the compounds are oxidized in the troposphere and at the same time get a close match in physical properties means turning to compounds that contain two carbon atoms, Manzer says. "If you replace chlorine in CFC-11 or -12 with a hydrogen, your boiling points are far too low," he says, "so you have to put a little more weight in the molecule by going to a two-carbon molecule."

Working with two-carbon fragments, however, adds the complexity of dealing with isomers. And there are a wide variety of reaction routes, starting from a number of possible materials, to the desired replacements. Each conceivable route has different problems associated

ditioners are currently the largest single source of CFC emissions in the U.S.

Technology for recycling CFC-12 from auto air conditioners is available now, says EPA's Anderson. Earlier this year, EPA and major auto manufacturers announced an agreement on standards of purity for recycled CFC-12 that will allow mechanics to reuse the old refrigerant without voiding the air conditioner warranty (C&EN, Feb. 6, page 6).

"I can understand how industries who make products they'd like to sell in nationwide markets are concerned about labeling requirements and restrictions and so forth that have popped up at the state level," Doniger says. "The most efficient answer to that, though, is for them to come to Washington and support national control measures. If we had a national auto recycling law, we wouldn't need to have 50 state recycling laws. If we had national labeling requirements, we wouldn't need inconsistent state labeling requirements."

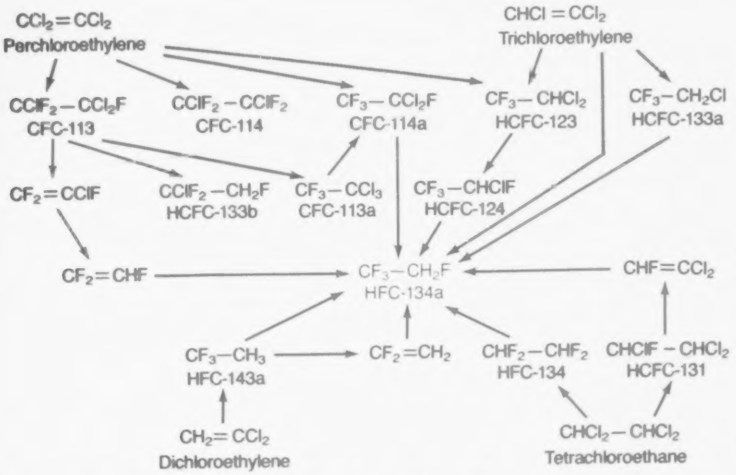
EPA's Claussen says that the agency has no plans to initiate such national regulations on its own. She would, however, look into it if asked to by the industries affected.

Claussen also asserts that EPA has no plans to restrict the use of HCFCs, although some politicians and environmentalists are calling for controls. CFC producers have been concentrating on developing HCFCs and HFCs as substitutes for the fully halogenated compounds. And the current refrigerant of choice for home air-conditioning in the U.S. is HCFC-22 ($CHClF_2$).

The hydrogen atoms on HCFCs make them susceptible to oxidation in the lower atmosphere. But some fraction reaches the stratosphere where UV radiation can release chlorine atoms that catalyze ozone destruction.

"I think in the end you have to be practical," Claussen says. "It is more important to get out of CFCs by some date certain than to regulate the HCFCs. And you need the HCFCs, for at least some CFC uses, in order to do that. If you use HCFCs wisely and not that much, it is probably okay. But I don't want to specify in a regulation how much is wisely, or what uses. On the other hand, I want to monitor exactly how much is being produced and what it is being used for, on a worldwide basis."

But pressures are mounting for restrictions on the future output of HCFCs. In the international arena, there was limited discussion at the May Helsinki meeting of whether HCFCs should be included in the renegotiations of the Montreal protocol. In the U.S., a draft bill, circulating in the Senate, would limit the time period over which HCFCs could be used. At the extreme, Greenpeace has called for banning all production and new consumption of HCFCs. And both NRDC and FOE hold that future limits on HCFCs must be spelled out now.



with it. Each has to be explored if the best process is to be found.

"For example, look at HFC-134a (CF_3CH_2F)," Manzer suggests. "You can imagine starting from several different chlorinated feedstocks—Perclene ($CCl_2 = CCl_2$) or Tri-Clene ($CHCl = CCl_2$). Then look at the number of reactions that have to take place as you add fluorine and go through various intermediates: You've got a real nightmare on your hands. Separating these materials is really what gets us into difficulty from a process development standpoint."

Manzer points out another problem. Hydrogen fluoride, which is present in the addition and exchange reactions en route to the substitutes, tends to form unpredictable, hard-to-manage azeotropes with many fluorocarbons.

"The HCFCs and HFCs are a problem too from a catalyst standpoint," Manzer says. "They are less stable in the lower atmosphere, which is why they are acceptable as substitutes. But they are also less stable on catalyst surfaces. For example, when you have hydrogen in a two-carbon fragment you can eliminate HF or HCl. A significant amount of that takes place on some catalyst surfaces. That creates a real headache for many of us in the development effort, because the resulting olefins are toxic and you've got to remove them from the final product."

Despite the complexities involved in developing processes that can be commercialized, Manzer says his staff of chemists and chemical engineers are highly motivated and excited by their work. "It's not everybody that has a chance to have an impact on the entire world," he says. "Normally within an R&D organization it may take 10, 15, or 20 years before your catalyst research ever gets commercialized. Now we are talking about commercial plants within two or three years after we have done the chemistry. That is very satisfying."

"These chemicals are useful because if you use them now you can get rid of the hard CFCs that much sooner," Doniger says. "But we want to make sure we don't have topsy-turvy growth that slows down or even prevents the reduction of atmospheric chlorine levels and contributes to global warming."

Doniger says that before 1986 there was not much development work on HCFCs and HFCs. Until it was clear that restrictions would be placed on the existing CFCs, companies had no incentives to invest in more expensive alternatives. "As we put HCFCs into service we ought to continue the research—both from chemical companies and users—into other ways of getting the job done with less and less of those chemicals and ultimately none at all," he says. "If you create the false impression that HCFCs have an unlimited future, there will be no interest in working on a better answer."

But the idea of a limited future is causing the chemical companies to balk. "We are very disturbed by the regulatory uncertainty," says Allied-Signal's Corcoran. "We plan to produce a full line of substitutes. But when we get to the point where the management committee has to approve plans for large-scale investments—a quarter of a billion dollars over a decade—if these kinds of restrictions go through it will be much harder to justify."

Du Pont's McCain adds: "We have not decided to go forward in the alternatives business. We are making small-scale plants. But if in a few years, when we have to get authorization for world-scale production facilities, we don't anticipate we can make money, we won't do it. Faced with potential regulations like that, why would any reasonable businessperson want to invest in something that would have a short lifetime?"

Doniger suggests that a balanced position in the middle is available. Industry, he argues, should work toward a regulation that would allow companies enough time to recoup their investments and then get out of the business. "At least they'd know that the cloud over those chemicals isn't going to result in the rug being pulled out from under them two, three, or four years down the road," he says.

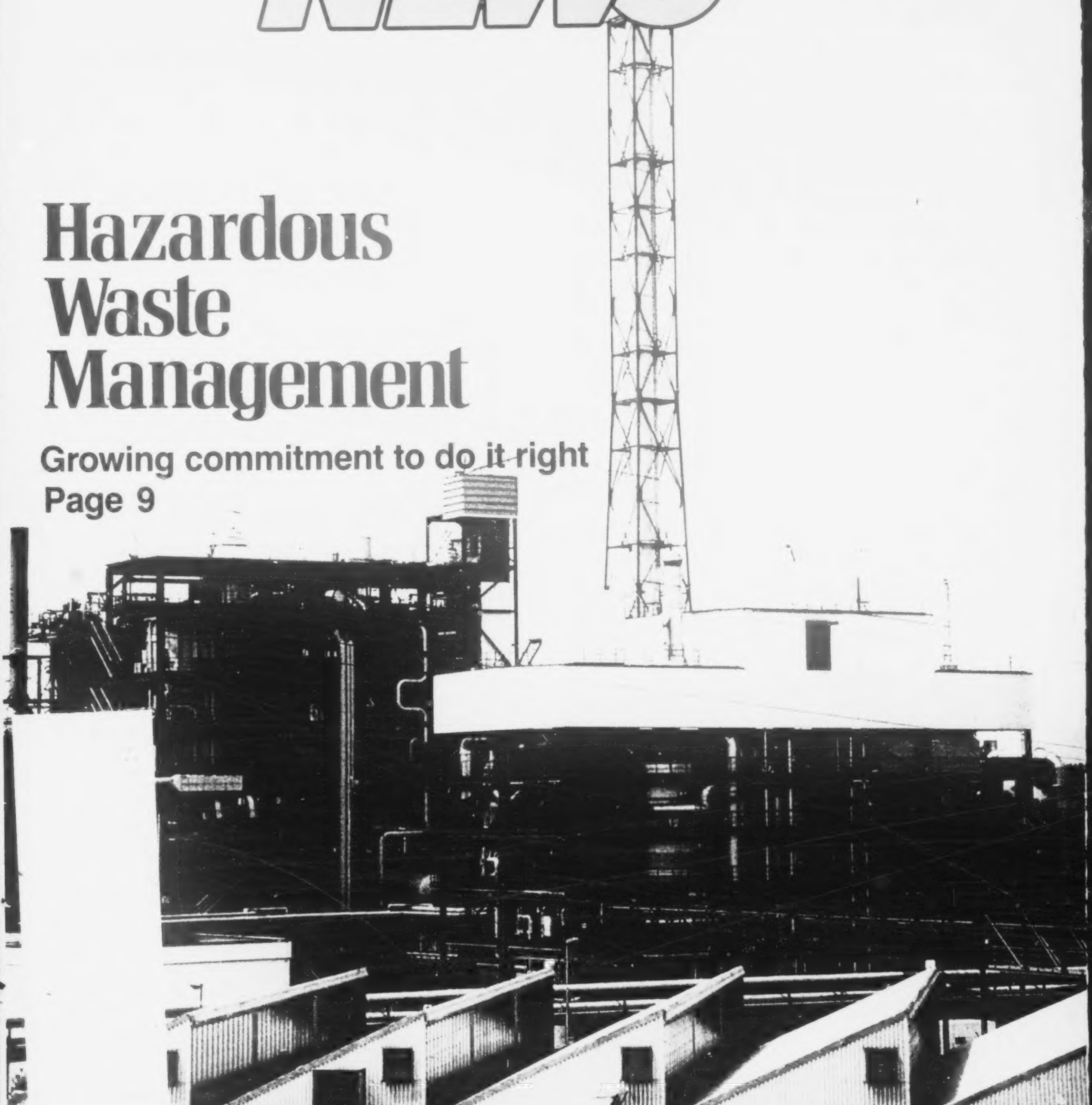
In the meantime, the uncertainty continues. For the moment it is limited to companies that produce and use CFCs and that are trying to plan for the future. But it will not be long before the effects of limited supplies of CFCs extend to the consumer.

"I don't think people have any idea of the impact this is going to have over the next few years," says Leo E. Manzer, research manager at Du Pont's central research and development department. "It's not going to be until people can't get their air conditioners charged up and have to suffer in the kind of weather we've had in the last few weeks that they'll realize how important CFCs are in all aspects of life." □

JULY 31, 1989

CHEMICAL & ENGINEERING

NEWS



Hazardous Waste Management

Growing commitment to do it right
Page 9

CHEMICAL & ENGINEERING
NEWS
JULY 31, 1989

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News of the Week

- **Second-quarter earnings for 1989 show continued decline for chemical industry.** Page 4
- **House acts to cut R&D appropriations budgets.** Page 5
- **Ethylene expansion should not lead to market glut.** Page 5
- **Bristol-Myers and Squibb to merge to form world's second largest drug company.** Page 6
- **Composition of science advisor-designate Bromley's science policy team is beginning to take shape.** Page 6
- **Citizens' action groups join to oppose use of plutonium on spacecraft.** Page 6

Cover: Bayer's hazardous waste incinerator at Leverkusen, West Germany. Photo by C&EN's David J. Hanson

Letters 2

Concentrates
Business 19
Government 24
Science/Technology 32

The Departments
Software/Database Update 40
Meetings 53
Newscripts 76

Business

U.S. fertilizer use is forecast to rise 2 to 4% this crop year to over 20 million tons. **Page 21**

Japan's chemical industry will continue its strong growth, largely fueled by domestic demand. **Page 23**

Government

Science adviser-designate D. Allan Bromley sails through confirmation hearings, is expected to receive Senate approval soon. **Page 25**

How corporate restructuring is affecting R&D activity remains unsettled, despite spate of studies on the matter. **Page 27**

Fray over how to amend the Clean Air Act has been joined by Congress' Office of Technology Assessment. **Page 28**

Science/Technology

Ceramic and metallic membrane-type devices from Du Pont extend applications of membrane separation technology. **Page 34**

Historical significance of Apollo 11 lunar landing debated in symposia as U.S. celebrates 20th anniversary of the event. **Page 35**

New Willard H. Dow Laboratory at the University of Michigan has total floor space of 270,000 sq ft. **Page 37**

Books

One-sided rebuke of professors and academic culture is, nonetheless, important reading for all concerned. **Page 42**

ACS News

Council likely to face three petitions—late-breaking symposia, meeting programing responsibility, and member exclusion from meetings—at its meeting in Miami Beach. **Page 45**

News Focus

Chemical companies are coping with federal hazardous waste disposal laws by generating less waste and by increasingly relying on a growing waste treatement industry. Page 9

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LETTERS

Women in chemical sciences

SIR: While browsing through the June 5 issue of C&EN, I was struck by an apparent paradox concerning two different items. The first was in the ACS News section (page 27). The Women Chemists Committee reported on a well-attended symposium entitled, "What ACS and Its Members Can Do To Encourage Women in Chemistry."

The second item (page 18) was the report of the 20 U.S. finalists for the International Chemistry Olympiad—not one of which is female. Although the short article did not explain how the finalists were chosen, it mentioned that the final 20 came from a group of 700 outstanding high school students. It is hard to imagine that there was not a single young female chemist among the 700 students who was competitive with the 20 plus 4 alternates chosen.

Since decisions made by committees—such as the local selection committees in this case—are always based on at least somewhat subjective information, a bit of sensitivity to the low representation of women in chemistry could have helped to identify appropriate candidates. Indeed, one wonders whether there were any women on the selection committees. If ACS and its members are serious about encouraging women in chemistry, they should do so at all levels, from the youngest students through professional chemists.

Clearly, an opportunity to do just that was neglected in the selection process for the Olympiad participants. Although this affects only a small number of people, it is symptomatic of the larger problem of getting and keeping young women interested in careers in the chemical sciences.

Rachel E. Klevit
Assistant Professor
of Biochemistry
University of Washington

Nuclear power

SIR: If there is no future for nuclear power, as Harvey Wasserman proclaims (C&EN, June 5, page 3), then prepare for rationing. You may call it compulsory conservation if a euphemism is more palatable. The fact remains that we cannot meet even the relatively modest air quality goals proclaimed by President Bush and continue to generate unlimited electricity by burning fossil fuels.

I rather doubt that the nuclear power industry is the greatest managerial disaster in U.S. history. In any event, it has plenty of company. Just read the report on the Massachusetts Institute of Technology productivity panel that begins on page nine of the same issue. The U.S. seems to do very well in producing managerial disasters, if you choose to believe the MIT panel.

In the distant future, we will have new energy sources. But anyone who believes that sun, wind, tides, and (con) fusion will contribute significantly to our energy budget before the turn of the century also believes that the tooth fairy is about to begin neutralizing acid rain as he (or she?) flies from place to place every night.

J. M. Eby
Pennsville, N.J.

Funding undergraduate science

SIR: The article about Bassam Shakhashiri's excellent work in pushing for funding in science education (C&EN, June 5, page 12) raises many excellent points. In a very real sense, our role as a world leader in science and technology is at stake, and the only solution is more support at all levels for science, math, and engineering education.

One point that was not raised in the article was the lack of funding for the undergraduate colleges, which yield about half of all students who enter graduate school but have a very small part of the total science education budget. We in the undergraduate colleges struggle against long odds to support students in summer research activities and to maintain our own research viability. The majority of funding goes to support graduate institutions. I am not suggesting that we should not provide excellent graduate opportunities, but only that we must make sure that the foundations on which these graduate institutions rest, the major sources of their students, must also be well nurtured.

The major program established in the past few years for support of undergraduate research, the National Science Foundation Research Experiences for Undergraduates program, has gone almost exclusively to universities. At the same time, we struggle to support our undergraduates by begging money anywhere we can. We have more students, faculty resources, and equipment than we can support in the summer. This year we had students begging for the opportunity to do research with us who could not be accommodated. It is reaching the point where we find ourselves spending more time trying to get

Hazardous Waste Management: Planning To Avoid Future Problems

Waste generators as well as those who dispose of wastes strive to meet treatment and disposal rules responsibly, see reducing waste at source as key to these efforts; new service firms form to help solve problems

David J. Hanson, C&EN Washington

The complex web of laws and regulations spun in the U.S for the treatment and disposal of wastes has had several effects. Owners and operators of facilities that generate chemical wastes have become very concerned about their responsibilities to dispose of those wastes correctly, and a large industry has grown up to help solve their problems. Most recently, companies that generate waste not only are trying to handle it properly but are also trying to minimize the amounts of waste they generate.

The two principal federal laws that try to control hazardous wastes are the Resource Conservation & Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation & Liability Act (Superfund). Both are administered by the Environmental Protection Agency. RCRA is designed to ensure that hazardous chemicals are not discarded in such a way as to cause harm to human health or the environment. First passed in 1976 and strengthened by the Hazardous & Solid Waste Amendments of 1984, it provides for "cradle to grave" management of more than 450 chemical wastes listed in the law as hazardous. It requires specific permits for treatment, storage, or disposal of hazardous wastes and provides for a manifest-tracking system to ensure proper handling of currently generated wastes.

Superfund, on the other hand, provides for the cleanup of old waste sites—landfills, waste lagoons and ponds, and warehouses—where hazardous chemicals have been abandoned while still potentially dangerous. Nearly 90% of the more than $10 billion to be raised by 1991 for Superfund will come from taxes on basic chemicals. Currently EPA has a list of more than 1000 abandoned sites on its National Priority List. Either the government uses the fund to pay for cleaning these sites or it gets the companies responsible for the wastes to pay.

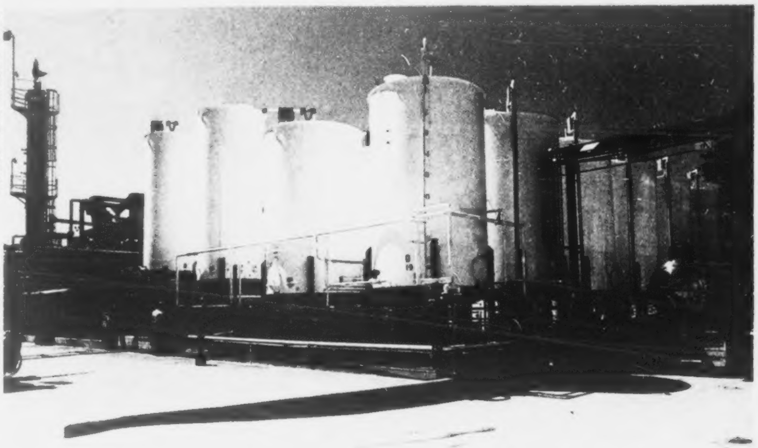
C&EN staff photo

Too many drums of hazardous waste are forcing industry to look for minimization methods

Although the two laws overlap in their regulation of hazardous wastes, it is RCRA that actually affects the most companies over the greatest period of time. EPA estimated in 1986 that more than 650,000 companies generated hazardous wastes in the U.S but that more than 99% of the waste volume came from 2% of those companies that are considered large-quantity generators.

In the past year, manufacturers generated more than 290 million tons of hazardous waste regulated under RCRA. Less than 5% was solid waste, the rest was wastewater. Industry is well aware of the volume of waste and of the high costs of trying to comply with the laws. As a result, many companies are making major efforts, often begun years ago but taking on new life in recent years, to try to reduce that amount of waste.

RCRA is a complex law, made more so by the 1984



Chemical Waste Management photo

Solvent recovery tanks represent an easy way to reduce hazardous waste

amendments. Congress will again be taking up reauthorization of RCRA, probably not seriously until next year, but almost five years after passage a number of issues that still need to be settled are coming to the fore.

One of these issues has been the impact of the so-called land-ban rules. Congress listed land-disposal deadlines for specific wastes it considered hazardous and ordered EPA to ban the land disposal of any of these after their deadlines unless the wastes have first been made nonhazardous. These materials include "dioxins," certain organic solvents, a group of various chemicals called the California List, and a long list of industry waste streams. One of the main reasons for completely banning some wastes was to force companies to drastically reduce the volume of those chemicals or to stop generating them entirely.

Morton L. Mullins, director of regulatory affairs for Monsanto in Washington, D.C., says the land-ban rules proposed so far have resulted in some catch-22 situations for the chemical industry. "There are a number of situations," he says, "where you just can't do [the required treatment] or you simply can't afford to do it." The land bans have caused a lot of consternation just because they have been on such a fast track, Mullins adds. In the latest instance, the ban went into effect even before the final regulations appeared in the *Federal Register*.

EPA has to stipulate the extent of treatment these wastes must have before they can be put into landfills. The agency bases its recommendations on what it considers the best demonstrated available technology. Mullins believes that the recommendation of a performance level for treatment gives the industry a lot of leeway for improvement. "Once you've established that level of performance," he says, "then you are not only free but encouraged to go out and build a better mousetrap."

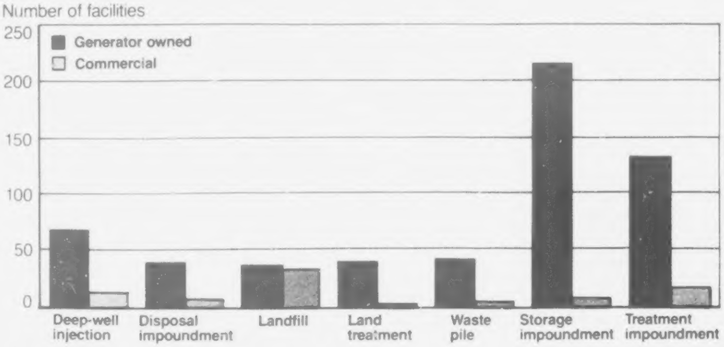
David Gramm, a legislative analyst for Dow Chemical, agrees that "when the land-ban regulations came out, a lot of companies got much more serious about waste reduction."

Joel Hirschhorn, senior analyst of waste issues at the Congressional Office of Technology Assessment, thinks EPA may have created the opposite effect. "Their approach in a sense freezes technologies where they are now by the kind of regulations they are putting out. They are telling people this is what you have to do with your waste with this kind of technology that is available now in the marketplace. From a technology development perspective, that's not a particularly good situation."

The land ban on disposal of specific, listed wastes and waste streams is to be in full effect by May 8, 1990. Regulations for the first two thirds of the wastes that appear on the industry waste stream list have already been published and the regulations for the final third, mostly wastes that are difficult to treat, are likely to be proposed this fall. One of the problems with the land ban has been the need to give a number of the waste treatment programs two-year exemptions from full compliance because of the lack of treatment capacity.

Critics of the program believe the extra time will probably not lead to new ways of treating the waste, but just result in more use of landfills and incineration. Jeffery Denit, deputy director of EPA's Office of Solid Waste, says the program can only move forward at a pace that the nation's industrial infrastructure can handle. "One thing we need is some dramatic increases in technological innovations and cost efficiency for

Land disposal facilities owned by waste generators outnumber commercial operations



Note: Data were compiled for 320 facilities in 1986 and 1988. Some facilities have more than one process.
Source: Environmental Protection Agency

both treatment and minimization," he says.

The upcoming debate over RCRA reauthorization is likely to focus on an issue the nation has been reluctant to face. That is what to do about the high-volume, low-hazard waste that Congress has specifically exempted from RCRA's regulation. Such wastes include cement kiln dust, utility company ash and sludge, phosphate mining and beneficiation wastes, uranium and other mining wastes, and gas and oil drilling muds and oil production brines, and some chemical process wastes. The amount of unregulated waste is not known, but it is believed to be a much larger volume than the regulated wastes. In fact, various estimates inside and outside government put the amount of RCRA-regulated hazardous waste at just 10 to 50% of the total waste volume.

Thus, the definition of hazardous waste is going to be an issue, according to Richard Denison, a scientist with the Environmental Defense Fund. "In our view there are a number of large waste categories that are sort of falling through the cracks, resulting from the binary system we have for wastes—either your waste is hazardous waste and you have a panoply of controls or it is not hazardous waste and you don't have to do much of anything." Denison says that under the 1984 RCRA amendments EPA is supposed to be analyzing the status of these unregulated wastes and writing reports for Congress. That has not been done. "Because of this, EDF has recently filed a deadline lawsuit against the agency on a number of these and other deadlines that it has missed," he adds.

Mullins from Monsanto says the definition of hazardous waste is an issue about which the chemical industry is deeply concerned. "The Chemical Manufacturers Association has recently petitioned EPA for a rulemaking in the area of de minimis concentrations of hazardous constituents in waste," Mullins says. "A problem with RCRA as it now exists is that once a waste is generated there is no way to get it out of the system, no matter how much you treat it or how low the level of the hazardous component gets." CMA wants to create some sort of tiered regulatory system for hazardous waste based on the toxicity threat of the waste. "Our methods would be better served if we had some sort of continuum of control ranging from totally inert construction rubble at one end to, say, dioxins at the other," Mullins says. "We could have three or four management regimes in between."

Hirschhorn recalls that when OTA did its report for Congress on hazardous waste, one idea it promoted was a degree-of-hazard system, but Congress didn't buy it. EDF's Denison thinks that a tiered system for managing wastes has merit, but is concerned about how EPA would handle it. "The real problem that would arise is how you would implement such a system. The agency's meager resources devoted to enforcing the current system are not enough, and I think the whole problem would be exacerbated even more under that kind of proposal," he says.

A basis for discussing hazardous waste issues is the bill, S. 1113, introduced this year by Sen. Max S. Baucus (D.-Mont.). It is similar to a bill he proposed during the last session of Congress and has some provisions that worry industry observers. The biggest issue is the attempt to set statutory goals for waste reduction. Basically, the bill would require companies to certify that, for any process, less than 5% of the beginning material is ever released into the environment, either as emissions or waste.

"In a lot of cases, this doesn't make any sense," says Mullins. "I think we will come out better without these kinds of arbitrary restraints." Denison agrees in part: "While the concept makes sense, where you set the numbers and how you measure the parameters is very difficult."

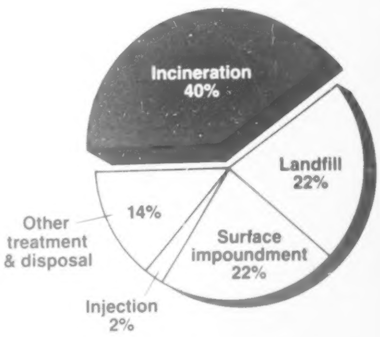
These ideas for streamlining RCRA may come to naught. The 101st Congress seems much more concerned about imposing stricter controls on municipal solid wastes than they are about hazardous wastes. "There is no sign right now that there will be any significant attention in this RCRA reauthorization to hazardous waste," opines Hirschhorn. "It's feasible that Congress could take a small action like asking for a study, but that might be all."

Even if Congress wanted to move on hazardous waste, its work would be impeded by a serious lack of comprehensive recent data. Except for some chemical industry data and estimates made by industry analysts, almost no studies have attempted to quantify the extent of the hazardous waste problem or determine what actually happens to those wastes. Since the 1984 reauthorization, when in-depth studies were done by OTA, EPA, and the Congressional Research Service, Congress has not asked for any further analysis of the issue.

This lack of data just adds more

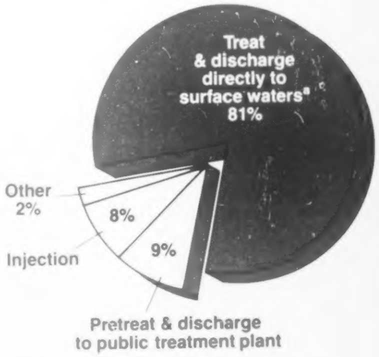
Chemical industry relies on incineration for solids...

Hazardous solid waste



...treats wastewater on site before discharge

Hazardous wastewater



Note: Based on a survey of selected chemical plants
a Treated by plant with a National Pollution Discharge Elimination System permit
Source: Chemical Manufacturers Association

Europeans continue to use incineration on large scale to destroy hazardous wastes

As might be expected, the various nations of Europe are handling their individual waste problems in a variety of ways. An examination of the hazardous waste practices in two countries with large chemical industries—Switzerland and West Germany—and in one primarily agricultural country—Denmark—shows how approaches may vary.

There are some common threads. Incineration is the preferred method of destroying wastes, with the resulting slag or ash being placed in landfills. Incinerator capacity, however, is very tight, and usually leads to facility expansion, a solution that, in turn, generates environmental concerns.

Environmental regulation is a fairly recent phenomenon in Switzerland, which has a very active chemical industry. Its first major environmental law was passed in 1983 and environmental impact statements were not required until 1988.

In prior years Switzerland had a fairly bad reputation when it came to managing hazardous wastes and had had a number of serious episodes involving leaking landfills. Today, according to Swiss environmental officials, most solid hazardous waste is incinerated and most liquid hazardous waste is used to fuel cement kilns. However, incinerator capacity is such that a lot of material is sent out of the country for disposal.

Thus, current plans call for four new regional incinerators for "special wastes"—a designation that covers, as it does in most countries, not only industrial chemical wastes but also some products found in municipal waste streams. Each incinerator would handle all the wastes generated in its specific region.

One incinerator is being built by Ciba-Geigy in Basel, and the problems facing this new facility demonstrate the growing concern Swiss citizens have about hazardous waste disposal. Much of this concern was sparked by the Seveso, Italy, accident in 1976 that sprayed 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) over the town. The concern was further fanned more recently by a fire in a chemical warehouse in Basel that resulted in toxic chemicals being washed into the Rhine River (C&EN, Nov. 9, 1987, page 16).

Ciba-Geigy already operates a rotary kiln incinerator at its Basel plant as well as a pilot plant that is testing new technology for the proposed incinerator. That new incinerator, however, was the subject of the first "public" hearing ever held in Switzerland on an environmental issue. The June hearing allowed all parties an opportunity to present their opinions about building the facility. The final decision on the incinerator will be made by the federal environmental office. That decision has not been announced yet, but the office is expected to approve the state-of-the-art incinerator.

Most of the opposition to the Ciba-Geigy incinerator, apparently, was not generated by concerns about the safety of emissions. Swiss law requires monitoring of nitrogen oxides, hydrogen chloride, hydrogen fluoride, oxygen, and particulates. (This is more than is required of U.S. incinerators.) Rather, opponents were concerned about the lack of incentives in Swiss law for companies to push for source reduction of the wastes, a practice the growing environmental movement in Switzerland believes is necessary.

In neighboring West Germany, the situation is, on the whole, similar. Incineration is the main method for destroying hazardous, or special, wastes. In the central state of Hessen, for example, there is one large solid-waste incinerator—located in Biebesheim and owned by the state government—that is designated to burn all the waste generated in Hessen that cannot be treated otherwise.

An incinerator has been operating in Biebesheim since 1917. The most recent one was built in the 1960s. Its two rotary kilns handle about 50 million tons of waste a year, but demand has exceeded capacity. Some wastes are now being buried underground in salt caverns and still more, about 100 million tons per year of mostly household waste, has to be sent to East Germany for disposal. So a third unit, which would nearly double the facility's total capacity, is being planned.

Officials of the facility, Hessische Industriemull (HIM) in Biebesheim, say there is growing public opposition to the expansion. Although the facility would meet the most recent West German air emissions standards, the surrounding community is becoming concerned about any additional emissions. The principal worries are emissions of heavy metals, such as cadmium and lead, and of TCDD.

Federal officials say the new facility is necessary because the volume of hazardous waste is increasing. Under current West German law, all volatile organics have to be incinerated; only inert inorganics can be landfilled. A permit for the expansion will come from the Hessen government, but the public can challenge that permit and then a special hearing would have to be held. That could well happen.

Local environmental groups are a fairly recent phenomenon in West Germany, and most do not have the expertise or resources of comparable U.S. organizations. However, because enforcement of environmental laws passed by

fuel to the continuing controversy over whether there is sufficient treatment capacity to handle all the wastes generated. Despite efforts by industry to control the volume of wastes, most analysts of the hazardous waste issue see amounts increasing over the next decade. EPA's Denit says that currently only about 100 hazardous waste incinerators are operating in the U.S., both private and commercial, with operating permits pending for another 100.

Many liquid organic chemical wastes are currently burned in large cement kiln incinerators, which do not face the same regulatory restrictions as do commercial waste incinerators. These operations, which burn the liquid wastes as blended fuel supplements do so under a provision that exempts this kind of "recycling" of material from the waste regulations. In the near future, these kilns will have to meet the same emissions standards for hydrogen chloride, hydrocarbons, and particulates as do other hazardous waste incinerators.

Landfills represent another problem. Because of tough RCRA permit requirements, most landfills that took hazardous wastes closed sev-

C&EN staff photo

Denmark's Kommunikemi incinerator to destroy 50,000 tons of waste yearly

the West German government are handled almost exclusively at the state level and because of the past history of close relationships between West German industry and the government, suspicion is growing as to whether the state's decisions are always in the public's best interest.

Just to the west of Hessen is the state of North Rhine-Westphalia, the most heavily industrialized state in West Germany and the site of Bayer's headquarters and largest facility in the town of Leverkusen. Bayer, like the HIM site, is faced with expanding volumes of waste, a result in part of the elimination of the option to burn hazardous wastes at sea and of pressure to halt the export of wastes to East Germany or the U.K.

Because North Rhine-Westphalia as a whole generates a large amount of waste and has little space to put it, using landfilling exclusively is not really an option for Bayer. Despite this situation, company officials say the integrity of landfills has been improved since the 1960s. Clay barriers and thick plastic liners, as well as goundwater monitoring, are now required for such facilities. But the landfills have been in use for a long time, and the older waste is still being slowly leached into the Rhine River above the town. So Bayer is expanding its incineration capacity at Leverkusen. That expansion will permit it to burn nearly 100,000 tons of waste per year, some of which would include hazardous waste from the municipality.

Bayer's plans to expand its incineration capacity have not drawn much environmental opposition from the local community, which largely depends on the company for work and has lived comfortably with this plant for more than 100 years. The community may also have been reassured by pronouncements by local officials—who have been monitoring for health effects for many years—who say they have not seen any adverse effects caused by either the landfills or the increasing levels of incineration.

The opposition has come from national environmental organizations who, like their Swiss counterparts, believe that source reduction is the solution to hazardous waste problems and that industry is not doing enough to achieve that goal.

One of the most sophisticated waste handling systems is in Denmark, where the basic philosophy is that if safe disposal of hazardous materials is made cheap enough then companies or individuals won't throw them away unsafely. The country has established a nationwide system for collecting hazardous wastes, both from industry and cities, that is all transported and disposed of in one place—the town of Nyborg. The incinerator and landfill complex located there, called Kommunekemi, was founded in 1971 and is currently handling more than 100 million tons of waste annually. The government is planning to expand its capacity and is facing the same environmental opposition expressed in Switzerland and West Germany.

Basically the argument against expansion is the same. Organizations concerned about the long-term impacts of new incinerators and expanded landfill capacity believe a lot more could be done in waste reduction. In Denmark especially, the government's efforts to keep disposal costs low remove any incentive for waste generators to reduce hazardous wastes. There are also complaints about the landfill, which the government openly admits leaches pollutants into the sea where dilution is expected to counter any toxicity. There are, though,. reports of fish kills and some area waters depleted of oxygen.

The town of Nyborg, interestingly, does not seem bothered by its being the center for all hazardous waste in the entire nation of Denmark. In fact, it seems a little proud of the distinction. For its trouble, the city does get steam heat from the incinerator for its public buildings, and the unit also generates electricity.

Europeans do not have the institutions in place to challenge hazardous waste management decisions once they have been made by their governments. They also seem more willing to accept such decisions as being in the nation's best interest, without the legal acrimony so often present in U.S. waste management issues. But discontent is growing, and the increased prominence of groups like the Green Party are forcing people to look more closely at how waste decisions are made. Both industry leaders and government officials alike foresee more difficulty in handling hazardous waste problems.

eral years ago. Although the few commercial facilities left have large capacities, EPA doesn't know how long they will last. Considering the difficulty that new facilities, either landfills or incinerators, have in getting permission from local communities for construction, new commercial treatment facilities will come on line very slowly, if at all.

As a result of the RCRA rules, and the need to reduce emissions because of the Superfund toxic emissions inventory, most companies are searching for new processes and new technologies for the treatment of waste, says Robert F. Olfenbuttel, director of waste minimization at Battelle Columbus Laboratories. "Everyone now wants to optimize their process operations to be sure they get wastes that can be recycled or try to take the unused products and recycle them back into the production stream," he says. One of the results of this are dozens of small technology firms trying to break into the market with new methods for reducing hazardous wastes. Because more than 90% of the wastes generated are treated at plant sites, many of these new treatment technologies are add-ons to existing equipment.

Product sales to exceed service revenues by 2000

$ Millions	1977	1988	1993	2000	Average annual growth 1977–88	Average annual growth 1988–93
HAZARDOUS WASTE PRODUCTS	$120	$3500	$ 9,300	$23,000	35.9%	21.6%
Treatment chemicals	40	520	2,550	9,000	26.3	37.4
Incineration equipment	40	1600	4,000	8,500	39.8	20.1
Processing equipment	10	340	1,020	2,700	37.8	24.6
Analytical instruments	25	390	700	1,100	28.4	12.4
Other products	5	650	1,030	1,700	55.7	9.6
HAZARDOUS WASTE SERVICES	385	6200	10,900	20,000	28.7	11.9
Transportation	185	2560	3,770	4,700	27.0	8.0
Consulting/engineering	5	700	1,400	3,500	56.7	14.9
Remediation/cleanup	neg	645	1,290	3,400	—	14.9
Incineration services	10	370	920	2,500	38.9	20.0
Analytical testing	35	610	1,070	2,300	29.7	11.9
Landfill disposal	15	605	1,370	2,000	39.9	17.8
Other services	135	710	1,080	1,600	16.3	8.8
TOTAL	$505	$9700	$20,200	$43,000	30.8%	15.8%

neg = negligible. **Source:** Freedonia Group

One of the reasons for developing add-ons is that most production processes are unique and require custom treatment designs. When waste management specialty companies, such as Chemical Waste Management of Oak Brook, Ill., go into a plant, they have to be flexible. "One of the key issues in our business is variability," says George Vander Velde, Chemical Waste's vice president for science and technology. "Waste streams vary a lot from plant to plant, and even within a company. Wastes also vary from day to day for a lot of reasons." One new system Chemical Waste is developing as an add-on to existing plants is an evaporator for wastewater. This evaporator, according to Vander Velde, uses a proprietary catalyst for oxidizing organics directly to carbon dioxide and very pure water. Any hydrochloric acid, a frequent by-product of wastewater treatments, can be removed easily by alkaline scrubbers.

Olfenbuttel says separation technology is becoming key to reducing wastes. By more efficient removal of the pollutants from water streams, companies can reduce their volume of wastes. Battelle is testing an electromembrane-technology process for high-yield separation and concentration of hazardous wastes.

Traditional specialty chemicals companies that offer treatment chemicals and waste management services, like Nalco Chemical in Naperville, Ill., are widening the scope of their products. "We are looking at better ways to control the separation process," says Nalco's Ron Schild, marketing manager for the company's basic industry group. "We are trying to automate the process to get the optimum sludge dryness, the clarity of the water, and [to] minimize the amount of chemical used. We've introduced some new automation schemes this year that will save money and help the minimization of sludge."

Schild believes the treatment industry is moving rapidly into the area Nalco calls bioengineering. "Biological treatment has been around for many years," he says, "because microorganisms can successfully metabolize a lot of substances." His company is expending great effort to find naturally occurring organisms—not "create" new organisms by genetic engineering or gene splicing—that can degrade common hazardous waste chemicals such as phenols and polychlorinated biphenyls. "This treatment technology has improved a lot in recent years, to the point where EPA recognizes what these organisms can do in terms of bioaugmentation of existing processes or even remediation of waste sites," Schild adds.

Nonetheless, this type of treatment will only provide some of the answers. Although biotreatment prevents emissions of hazardous pollutants and eliminates waste, it does so after the fact. George Muhlbach, head of the environmental programs at Ciba-Geigy in Wilmington, says the future will be more toward specific changes in the process itself and less end-of-pipe treatments. "In water, for example, waste treatments placed at the end of the stream will be looked on more as a polishing step. Most of the waste reduction will be done with additional in-process changes and by changing the chemical used," Muhlbach says. He emphasizes that he does not limit the changes to just hazardous wastes. "We are trying to minimize all wastes. We have specific programs for our research and development people to address the whole process from the point of view of reducing the waste stream," he adds.

There is a recognized hierarchy for managing waste reduction. The first thing a company can do is improve housekeeping. Following that is to substitute less hazardous materials for ones currently used. Then methods for recycling and reusing materials are developed. Then comes modification of the process to reduce waste. The last option is simply disposal.

Monsanto's Mullins says, "I think we've reached the point now where virtually everybody in the industry is sensitive to that hierarchy of desirability of pollution prevention. Institutionalizing that, and getting it moved all the way back to the research and the manufacturing ends, is the real challenge."

Success stories of chemical plants getting dramatic reductions in hazardous waste by making what seem to be obvious improvements are becoming almost common. One example cited by Mullins at a recent Congressional hearing on waste reduction is typical. Monsanto's Port Plastics plant near Cincinnati managed to reduce loss of a particular resin more than 75% by using better gasket materials, improving maintenance procedures, and get-

Waste volume will grow despite reduction efforts

Millions of tons	1977	1988	1993	2000	Average annual growth 1977–88	Average annual growth 1988–93
TOTAL	131	291	380	510	7.5%	5.5%
BY TYPE OF WASTE						
Heavy metals	51	114	149	196	7.6	5.5
Organic chemicals	42	100	132	180	8.2	5.7
Petroleum derived	16	33	44	60	6.8	5.9
Inorganic chemicals	17	35	43	55	6.8	4.2
Other hazardous waste	5	9	13	19	5.5	7.6
BY METHOD OF DISPOSAL						
Landfill/surface impound	12	200	225	165	29.1	2.4
Treatment/stabilization	2	13	50	150	18.5	30.9
Incineration	neg	15	35	95	—	18.5
Resource recovery	2	12	30	75	17.7	20.1
Deep-well injection	5	14	15	10	9.8	1.4
Illegal disposal	110	35	20	5	−9.9	−10.6
Other methods	neg	2	5	10	—	20.1

neg = negligible. **Source:** Freedonia Group

ting unused resin to polymerize thus rendering it nonhazardous. Mullins says the plant saves $200,000 yearly in reduced raw material and waste management costs. Such reductions are very process-specific and consequently will make significant waste reduction look like a very slow process.

EPA assumes that, eventually, one third of all hazardous waste generated can be eliminated before it is produced. Among the programs the agency has under way to encourage waste reduction is a national computer clearinghouse, which provides waste reduction information to those interested.

Overshadowing all the corporate efforts on hazardous waste reduction and waste management is the Superfund law, particularly a provision that sets strict and several liability on anyone involved at a site. That is, EPA can hold any company liable for cost of the entire cleanup of an abandoned site regardless of the amount of wastes that that company placed into the site.

"This makes corporate management reconsider any type of waste management and forces them to think more about waste reduction," says Hirschhorn. Monsanto's Mullins agrees that this liability has changed attitudes. "There is a new awareness of the real economics, of the real liabilities of hazardous waste because we now have plant managers signing checks to pay for cleanups. The costs in dollars are appearing on the bottom line."

That is one of the main reasons why more than 90% of hazardous wastes are treated on the same site they are generated—to avoid the liability that comes with having to put that waste somewhere else. It is also a reason why chemical companies and other waste generators are becoming concerned with wastes that are not even currently regulated as hazardous. OTA's Hirschhorn says, "People who are disposing of waste today that is hazardous but not regulated under RCRA are going to get nailed under Superfund. It makes no difference if that waste is regulated today. A very high fraction of truly hazardous waste could be going to regular landfills perfectly legally. All of these will become, eventually, Superfund sites." Mullins concurs. "There is a real concern about the liabilities of disposing of waste not now regulated as hazardous," he says. "This is precisely the situation we had before Superfund. You could dispose of the wastes legally, but you were amassing this enormous liability."

The so-called Title III toxic emissions inventory required under Superfund is also having a major impact on waste management decisions. The inventory is a compilation of environmental release data on more than 325 chemicals that Congress listed as toxic under the 1986 amendments to the Superfund law. Virtually all of the data are made available to the public.

"I'd say the past year and a half has been very much a transition period in which we have been establishing new programs with a focus on the broader aspects of all wastes to all media, whereas we had just finished institutionalizing a focus on solid hazardous waste," Mullins says. Because the emissions inventory covers all releases of hazardous chemicals, it may be only a matter of time before all of the

Chemical Waste Management photo

Chemical Waste's hazardous waste landfill at Emelle, Ala., is U.S.'s largest chemicals are listed by somebody as hazardous wastes, and therefore have to be controlled as such. Mullins hopes the industry will not just have a knee-jerk reaction to this and treat these materials exclusively with end-of-the-pipe controls. "The big problem is to think first about source reduction and then about treatment," he says.

One very visible result of all the waste treatment requirements of RCRA and of the testing and remediation activities demanded by Superfund is a burgeoning hazardous waste service industry. And industry analysts expect that growth to continue at a rapid pace. William P. Weizer, vice president of the chemicals and plastics division of Freedonia Group, a consulting firm in Cleveland, has just finished an in-depth study of the prospects for the waste industry. It concludes that the industry will be a $20 billion service and product business by 1993. "There are more than 350 companies engaged in hazardous waste management," Weizer says. "Of these, the top 30 firms generate about 70% of the aggregate revenues."

Although these companies are expected to show rapid growth in revenues over the next 10 years, there are some adjustments expected in the industry as a whole. "We are starting to see some rationalization in the industry," says Michael E. Hoffman, industry analyst for the Salomon Brothers investment firm, "particularly in the remediation area."

"Early on in Superfund, just about anybody who could operate a backhoe was sending in bids on those projects. Now the financial hurdles are starting to keep some players out because they cannot provide the bonding required to bid on the federal projects," he says.

Robert Buhr at Moody's Investors Service sees much the same situation. "A problem for smaller companies was the anticipation of large amounts of Superfund work," Buhr says. "But EPA got bogged down and the revenues haven't come along as anticipated."

One of the things that will happen over the next several years in the treatment and disposal area will be some consolidation by larger companies. "There are a lot of little guys out there who do all right in their own regions, but they've got financial constraints and aren't able to grow. If you have an objective to be a national player, you need the economy of scale," Weizer says, adding that the push for improved technologies is the reason for mergers. "The main reason for consolidation is the technology, the money required for research and development, and commercialization of the product." Because of the consolidation of companies in the next few years, Weizer expects that the 70% of the revenues now collected by 30% of the companies will become 80% of total revenues by 2000.

From a different point of view, Moody's Buhr says that anyone trying to buy a waste management company will have to be careful. Some of them, those that are doing well, are going to go at premium prices. Others will not. "It is going to be a company-by-company situation," Buhr adds. "But the premium is not unreasonable because of the tremendous potential for growth."

The growth in treatment and incineration has been driven by federal regulations. Putting hazardous wastes in landfills is being discouraged because of the risks associated with soil and groundwater contamination, as Freedonia Group notes. Despite this, the group says the land methods of disposal, including landfills, surface impoundments, and deep-well injection, will continue to dominate the market over the next decade. This is because certain hazardous wastes, such as heavy metals and radioactive materials, are incompatible with such alternatives as pretreatment and resource recovery. These are the same materials that represent an increasing portion of hazardous waste as the government increases the number and kinds of wastes being regulated.

Concerns about too little or too much treatment capacity for hazardous wastes are discounted by industry analysts. Weizer says there is going to be enough landfill capacity but that it will get more expensive to dispose of wastes this way as time goes on. "They won't be as easy to find or as accessible as they have been in the past. They

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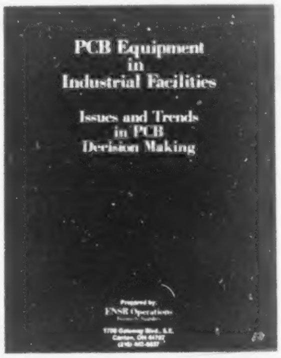

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might be farther out, and transportation costs will be higher." Salomon's Hoffman concurs, "If you take out the wastes that are subject to the RCRA land ban, and don't significantly increase the volume of those wastes in the pretreatment process, then there is probably 35 to 50 years of available landfill capacity." Weizer believes that some companies crying the loudest about landfill closings and insufficient capacity may just be trying to get people to think there is a crisis in order to justify charging higher prices.

Hoffman says that a number of persons argue that there is going to be an overcapacity in incineration. As EPA continues to issue new permits, commercial operations might suffer from a glut of incinerators. "We strongly believe this is wrong," he adds. "The incineration business shows signs of real resilience in the face of all the [public] opposition. And, there are not a lot of commercial solid waste incinerators."

Estimates are that about one fifth of all the increased hazardous waste volume that will result from new regulations will be incinerated. Hoffman believes that liquid incineration has reached its capacity, partly because a lot of liquids can be burned in cement kilns and industrial boilers and be classified as recycled waste. When these facilities have to meet the same environmental standards as regular incinerators, most will stop using blended wastes.

The cleanup, disposal, and minimization of hazardous wastes will continue to be driven by government regulations. New laws are likely to increase the volume and number of wastes being regulated and the laws are likely to remain complicated. Vander Velde says his salespeople have to spend a lot of time just explaining to people how to comply with the existing law. More regulations will not change that. Yet, chemical waste treatment is an exciting business to be in at this time, he says, with so many things going on.

Still, the public's concerns, as voiced by Congress and environmental activist groups, are going to carry a lot of weight in determining how the chemical industry and its wastes are managed for a long time to come. □

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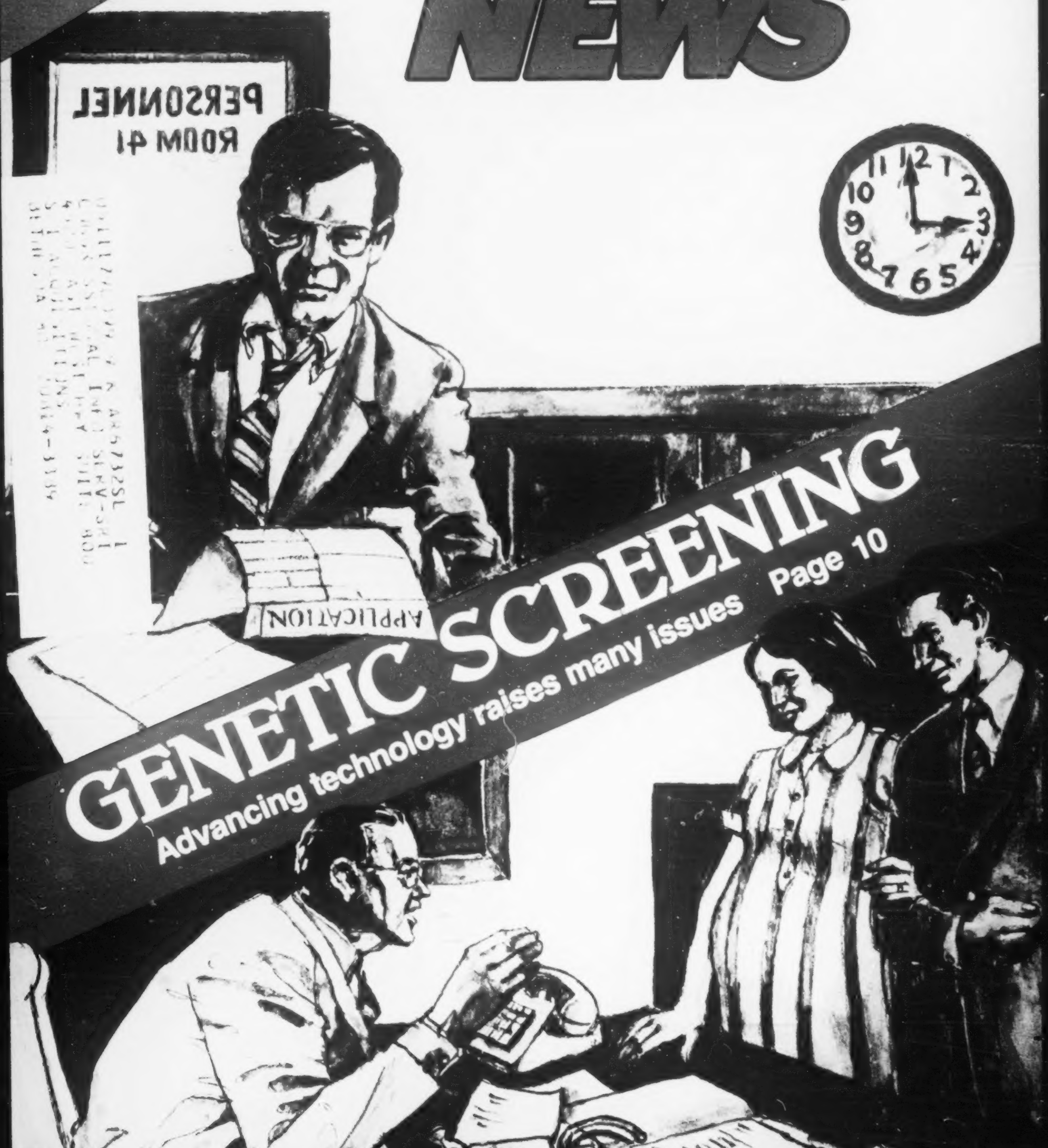
AUGUST 7, 1989

CHEMICAL & ENGINEERING NEWS

Rohm & Haas expanding operations in Europe Page 19


PERSONNEL
ROOM 41
APPLICATION

GENETIC SCREENING

Advancing technology raises many issues Page 10

Volume 67, Number 32
CENEAR 67 (32) 1–48
ISSN 0009-2347

CHEMICAL & ENGINEERING NEWS

AUGUST 7, 1989

News of the Week

- **Powerful Senator's anger at research porkbarreling has turned into amendment that may crimp lobbying practices.** Page 4
- **Italy's Montedison offers more than $1 billion for the stock it does not already own in U.S.-based operations of Himont and Erbamont.** Page 5
- **Department of Energy proposes five-year plan for waste cleanup at its nuclear facilities.** Page 5
- **U.S. government grants Akzo Chemicals exclusive license to implement bulk process that stops deterioration of books printed on acidic paper.** Page 6
- **Oil, Chemical & Atomic Workers Union helped stall startup of BASF plant in Geismar, La.** Page 6

Business

Rohm & Haas is thriving in Europe, despite declines in earnings from its European operations, partly as a result of currency changes. **Page 19**

Industry supports establishing consortia on superconductivity, according to survey conducted by Defense Advanced Research Projects Agency. **Page 22**

Government

NIH panel strips funding from vision researcher C. David Bridges after reviewing charges that he plagiarized work involving the discovery of an eye enzyme. **Page 24**

President Bush's clean air bill receives mixed reviews from Congress and environmentalists. **Page 26**

Science/Technology

Carnegie Mellon researchers synthesize new tin-based propellane that may shed light on bonding questions as well as prove useful for fabricating advanced materials. **Page 29**

Seiko Mead Co. introduces full-color copying system that features a photographiclike, film technology that does not use silver halide. **Page 32**

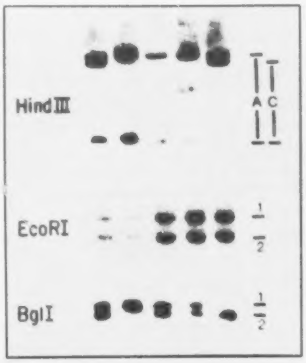
Books

Teaching writing by example, not by rules , is tactic taken in book for technical professionals and those who instruct them. **Page 33**

Letters 2

Concentrates
Business 17
Government 23
Science/Technology 28

The Departments
ACS Focus 35
Meetings 47
Newscripts 48



News Focus

Advances in genetic screening for defects that cause a variety of disorders may improve health care, but raise legal and ethical questions. **Page 10**

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LETTERS

Cheemotherapy entrenched

SIR: A. G. Engstrom (C&EN, June 12, page 2) has brought up cheemotherapy vs. chemotherapy again. When someone makes a clear mistake in pronouncing a chemical term, I agree that they should be made aware of it.

However, the pronunciation "cheemotherapy" is so firmly entrenched (Webster's Ninth New Collegiate Dictionary lists it first) that attempts to correct it would risk being viewed as parochial or egocentric. What we need today is fewer barriers to communication, not more. Loosen up, guys.

Robert Riesenman
Hammond, Ind.

SIR: Referring to the recent letters expressing concern over the mispronunciation of words derived from or relating to chemistry, my wife chuckled, "Don't chemists realize that the entropy factor may apply equally well to linguistics?" If so, we may be able to alter the rate at which mispronunciations evolve into common usage by applying the "scholarly influence" suggested by A. G. Engstrom, but we cannot stop the process.

Perhaps those who are concerned about the pronunciation of cheemotherapy should apply their energies to more important issues such as global warming (which, as its influence on the entropy term in Gibbs' free energy expression suggests, may be accelerating the deterioration of our language) and let my wife have the last laugh—as is her custom.

Albert L. Powers
Chairman, Science Department
Concord-Carlisle High School
Concord, Mass.

Material safety data sheets

SIR: I am pleased to see at last some interest and controversy being expressed in C&EN regarding the adequacy, or inadequacy, of material safety data sheets (C&EN, March 20, page 4; May 29, page 2). As every chemical professional knows (or should know), the material safety data sheet is the cornerstone of the Occupational Safety & Health Administration's Hazard Communication Standard (29 CFR 1910.1200).

For the past three years, I have been working in the area of chemical safety for a large, non-CPI company, and have become very familiar, if not always happy, with the care and feeding of hundreds of vendor material safety data sheets (since we do not prepare any of our own, we are dependent on those from our various chemical suppliers).

From this recent experience, two aspects of data sheets in general have concerned and frustrated me in my administration of the Hazard Communication Standard in the workplace. For some unknown reason(s), the format of the material safety data sheet was never mandated by OSHA. Both the older Form 20 and the revised Form 174 were recommended for use, but only the informational content was made requisite. Try submitting your federal income tax return on a form marked "essentially similar to Form 1040"! The net result of this laissez-faire situation is that material safety data sheets are published in dozens of formats, ranging from very complete four- to eight-page dissertations to two-page useless brevities, and it's confusing, at best, when one has to review many data sheets to find all the information one needs, under widely varying headings.

This confusion with format also makes it very difficult for emergency response personnel to find crucial information rapidly under demanding circumstances. In addition, now that computerized text readers are becoming more widely available, a standardized material safety data sheet format would be most useful for filing and retrieval purposes.

One could write a book about the broad spectrum of the quality of material safety data sheet information. As a corollary of the format problem, it follows that the longer data sheets generally contain much more complete chemical information than the shorter ones. However, many of the data sheets that I have reviewed are not worth the paper they're printed on, and very few comply with all of the information requirements of the Hazard Communication Standard [Paragraph (g)]. I am not aware of any OSHA policing activity in this area of Hazard Communication Standard compliance, but perhaps more attention should be paid to enforcing the requirements for material safety data

Correction

- July 17, page 24: The research leading to production of diamond powder using a microwave plasma was a collaborative effort involving Michael Frenklach, professor of fuel science at Pennsylvania State University, and Richard J. Koba, material scientist at Diamond Materials Inc., State College, Pa., along with Penn State ceramic science and engineering program chairman Karl E. Spear.

Superconductivity industrial consortia explored

Cooperative programs among industry, academia, and government often are advocated as a route to improve U.S. commercial competitiveness in high-temperature superconductor technologies. However, although a few consortia have been formed (C&EN, July 10, page 19), an industrial base is not yet established. The Defense Advanced Research Projects Agency (DARPA), created 30 years ago by the U.S. Department of Defense (DOD) to accelerate the development of new technologies, has surveyed industry to determine if an initiative on the manufacture of high-temperature superconductor products holds any promise.

DARPA's survey included questions on the planning of and participation in industrial consortia, government sponsorship of R&D, directions for R&D and manufacturing, and a plan for DOD involvement in high-temperature superconductor consortia. The results of the survey, based on the responses of corporate officers from 48 companies involved with high-temperature superconductivity, were compiled in a recently released report.

Kay Rhyne Adams, DARPA program manager for ceramics and superconductivity, states in the report that most U.S. companies, unlike Japanese companies, are taking a "wait-and-see attitude" toward manufacturing. Major U.S. corporations, such as IBM, AT&T, Du Pont, and Hewlett-Packard, do not have any near-term plans for manufacturing, the report adds, despite having extensive research programs. DARPA indicates that even those companies participating in its programs are "holding back." Thus, it appears that only smaller startup companies are moving toward near-term production.

Industry supports consortia on superconductivity

Total: 51 respondents to DARPA survey

Source: Defense Advanced Research Projects Agency report "Industrial Consortia for High Temperature Superconducting Technology"

However, 71% of the respondents believe that the technology is not too young to begin planning for an industrial base to support production. In fact, 94% indicated that they would consider being part of a government-sponsored consortium for superconductivity. Government sponsors are generally considered more desirable than private sponsors. In choosing between government agencies as potential sponsors, DARPA was rated the highest, preferred by 64% of the respondents, and the Department of Commerce, Department of Energy, and National Science Foundation followed with 22%, 18%, and 12%, respectively.

A proposal for an industrial-consortium such as Sematech's, which was created to bolster an existing semiconductor industry, was included in the DARPA questionnaire. The plan consists of three phases: funding companies through R&D contracts for two years while preparing a detailed plan for a high-temperature superconductivity consortium; establishing the consortium and a manufacturing infrastructure over a six-year period, moving toward production capabilities for electronic applications; and, continuing and moving the consortium's efforts toward high-power applications.

DARPA has an active materials- and device-oriented R&D program in high-temperature superconductivity, funded at an annual level of about $30 million. In 1988, the program included contracts with 24 companies, six government laboratories, six universities, and 23 subcontractors. DARPA and DOD have interests in advancing the technology and positioning U.S. industry to produce products that can be used in military systems. In the consortium plan, one role played by DOD would be as a small, but reliable, market for products. Products based on thin film technology are hoped for within the next three to five years with prototype production based on bulk materials by 1994.

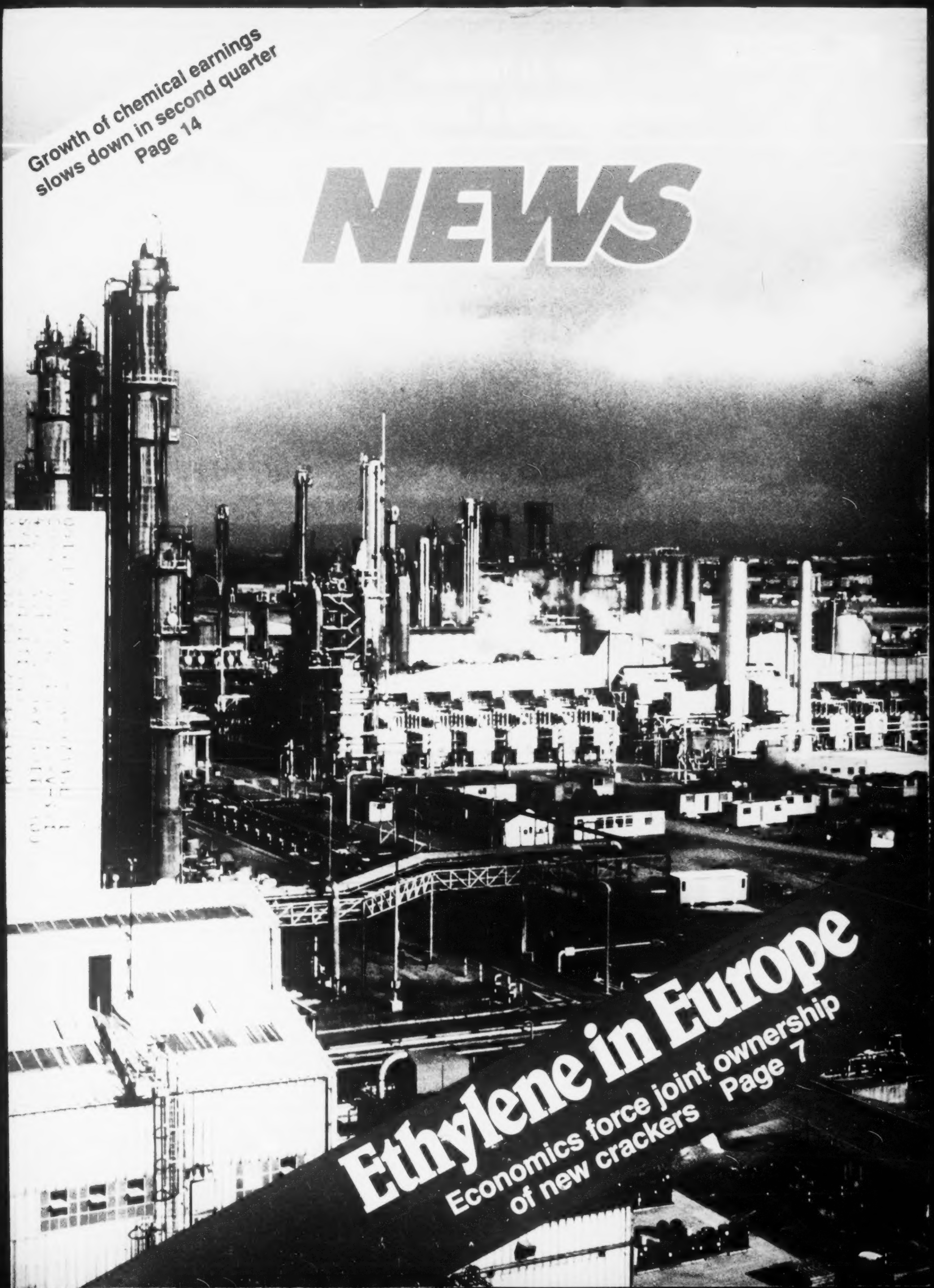
The overall reaction by industry to the proposal is favorable. A large majority, 73%, indicate both that a manufacturing consortium is needed and that the DARPA plan looks promising. However, industry comments suggest that the focus not be on military products alone. Most all agree that there is a need for the government to establish tax advantages, in the form of incentives for R&D or capitalization, for the development of high-temperature superconductivity technologies.

Despite difficulties and uncertainties concerning new superconducting materials, two thirds of the surveyed group do not consider the technology too immature to plan for building a manufacturing effort. Not surprisingly, the percentage of responses strongly in favor of the consortium approach corresponds very closely to the number of companies in the group already in consortia or collaborative R&D programs.

Responses to the survey stress some of the not unfamiliar issues that would arise in planning a consortium. These include evaluating materials, defining and prioritizing potential applications and products, continuing R&D efforts in material fabrication and processing, device development, and manufacturing science. In addition, the corporate officers believe that further thought is required to determine how a consortium would actually be funded, implemented, and operated. A large-scale integration of government, industry, and academia has not yet been attempted in the U.S.

The report also concludes that, although the desire and need for a consortium exists, Sematech may not be the appropriate model. It concentrates on competitiveness and manufacturing. In comparison, some believe that high-temperature superconductors are primarily in the research, not commercial, stage, and that discussions of manufacturing may be premature.

Ann Thayer



NEWS

Growth of chemical earnings slows down in second quarter
Page 14

Ethylene in Europe

Economics force joint ownership of new crackers Page 7

CHEMICAL & ENGINEERING NEWS

Volume 67, Number 33
CENEAR 67 (33) 1–48
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AUGUST 14, 1989

News of the Week

- **Japan's Teikyo University merges with West Virginia's Salem College to form Salem-Teikyo University.** Page 4

- **Chemical firms expand production in some sectors in response to effort to maintain market share.** Page 5

- **Virtual phaseout of CFC use and production by 2000 is possible says United Nations Environment Program review panel, but may prove expensive.** Page 5

- **Advisory panel to Utah state legislature votes to release $4.5 million for cold fusion research institute.** Page 5

- **EPA, in report of indoor air pollution problem, only recommends more research and consumer information.** Page 6

- **China to construct seven new fertilizer plants despite political and economic turmoil.** Page 6

Business

Chemical earnings show only 3% overall growth for the second quarter; of all chemical-producing companies, pharmaceutical firms looked best racking up an 8% gain. **Page 14**

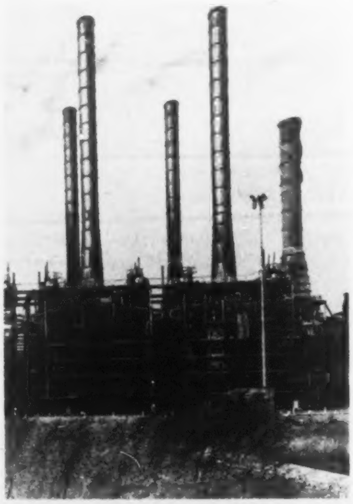
Extended Product Life, a Pennsylvania-based firm, looks to profit from Food & Drug Administration's ban on sulfites with its development of a nonsulfite-containing product that preserves fruits, vegetables. **Page 19**

Government

Congress active in setting 1990 budgets for various federal agencies, before August recess; committees address a range of environmental problems, other matters. **Page 22**

Science/Technology

Alternative fuels to petroleum are gaining increased attention, with oxygenates emerging as most promising candidate, Fischer-Tropsch process gaining new prominence. **Page 25**



Cover: BP Chemicals' ethylene cracker at Grangemouth, Scotland

News Focus

Economics are changing the way the European chemical industry approaches its ethylene strategy, forcing joint ownership of the costly new crackers needed to alleviate current tight market. **Page 7**

Letters 2

Concentrates

Business 12

Government 21

Science/Technology 24

The Department

Newscripts 48

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LETTERS

Remembering George Pimentel

SIR: Rebecca Rawls' portrayal of George Pimentel from impressions by his friends and associates (C&EN, July 10, page 27) touched all bases. I think Pimentel, in his winsome manner, would have enjoyed the account.

I spent some five years, during the 1960s, as his editor for the CHEM Study text materials. He was a taskmaster who was tough but always fair and honest. As a high school teacher, I thought I'd be awed by his presence. But his warmth and understanding allayed all my fears. He made me feel that my contributions were real and important.

It is ironic that Art Campbell passed away just a few weeks before Pimentel. These were two giants on whose shoulders the CHEM Study structure rests. No small wonder that the influence of this curriculum study was felt throughout the high schools of the world as well as in the grade schools and colleges. And all because of Pimentel's dogged determination, supported by Campbell and many others, that chemistry is indeed an experimental science and should thus be taught.

Pimentel would remind me that it is not what you know that is important. Rather, it is what you do with what you know that measures your worth. I will never forget him.

Saul L. Geffner
Southbury, Conn.

Epidemiological malpractices?

SIR: Irwin D. Bross alleges (C&EN, April 17, page 3) that the concept or theory that "a little radiation is good for you" is a "crackpot theory." He states, regarding my letter "Radiation epidemiology, extrapolation, and opinion" (C&EN, Jan. 23, page 2), that "not one of the listed references is from a recognized epidemiological journal." I commented earlier on the problems in "Scientific malpractice in epidemiology" (C&EN, April 9, 1984, page 76).

In a commentary on scientific malpractice in epidemiology [*CHEMTECH*, **19**, 269 (1989)], I noted that "when public policy is influenced or determined by statistical and other scientific malpractices, the risk of hazard to public health can be increased." The editors of *CHEMTECH* added a comment by Alvan R. Feinstein relating to epidemiology: "If war is too important to be left to military leaders, and medicine to physicians, the interpretation of epidemiologic results cannot be relegated exclusively to epidemiologists. The people who struggle to understand those results can be helped by recalling that statistics are like a bikini bathing suit: what is revealed is interesting; what is concealed is crucial" [*Science*, **242**, 1263 (1988)].

Also noted in the *CHEMTECH* article are surprising omissions in the 1988 National Academy of Sciences report, "Health Risks of Radon and Other Internally Deposited Alpha-Emitters," also known as the BEIR-IV report. For example, BEIR-IV evidently does not recognize, or is unaware of, the biophysical phenomenon of hormesis. Hormesis is "beneficial stimulation by low levels of nonnutrient agents that are toxic or lethal at very high exposure levels" [*New Engl. J. Med.*, **307**, 1449 (1982)]. BEIR-IV also "overlooks" all publications by T. D. Luckey on radiation hormesis [for example, *Health Phys.* **43**, 771 (1982)], and comparable publications by others. It is doubtful that all of these publications could have been inadvertantly overlooked. Was selective referencing employed?

Regarding inference of causality from correlation (favored by Bross?), R. Doll and A. B. Hill commented [*Brit. Med. J.*, **2**, 1271 (1952)] that "in the U.S.A., the death rate attributed to lung cancer in the different states is positively correlated with the numbers of physicians per 1000 inhabitants." The association was said to be "true independently of the correlation with cigarette consumption—which is also related to the number of physicians per 1000 inhabitants." Would Bross conclude from such data that physicians cause both cigarette smoking and lung cancer because of the correlations?

Regarding smoking and health, P. R. J. Burch [*Lancet*, **1**, 866 (1985)] analyzed combined epidemiological data of three studies that employed randomized sampling and smoking intervention. Control populations were compared with comparable populations that were urged by physicians to reduce or stop smoking. Burch concluded that it is "difficult to evade the implication of the methodologically reputable randomized trials; active cigarette smoking has little or no net carcinogenic action." For example, the Multiple Risk Factor Research Group reported the results of comparisons of mortality rates for randomized populations [*J. Am. Med. Assoc.*, **248**, 1465 (1982)]. Cancer mortality rates were found to be higher in the randomized population that was urged to reduce or stop smoking than in the control

Joint Ventures Likely Basis of European Ethylene Expansion

Substantial additions are being planned to overcome current tight market, but economic factors, including high cost of new crackers, are forcing joint ownership

Patricia L. Layman, C&EN London

Economics, including the initial cost of construction as well as the need to avoid overcapacity, are changing the way the European chemical industry approaches its ethylene strategy.

The most recent new ethylene cracker built in Western Europe, the Fife ethylene plant commissioned in 1985 in Mossmorran, Scotland, is a joint venture of Exxon Chemical and Shell Chemical. The only new cracker currently under construction in Western Europe is Finaneste's in Antwerp, Belgium—a joint venture between Petrofina of Belgium and Neste of Finland. But now, nearly a dozen other companies have proposed building or significantly expanding crackers, which could raise ethylene capacity in Western Europe from 14.5 million metric tons per year to nearly 19 million metric tons.

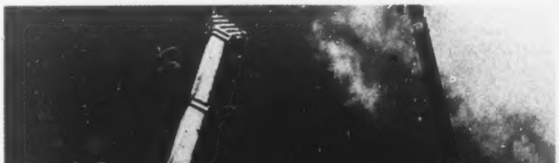
Although there is general agreement that the industry is running flat out and some more capacity is needed, on the face of it, that massive an increase is an appalling scenario. Only in the past two years has ethylene resumed a healthy balance sheet, following a glut of overcapacity in the early 1980s.

However, at least two of the producers who have announced possible crackers on the continent are actively seeking joint-venture partners, and others are seriously weighing this route.

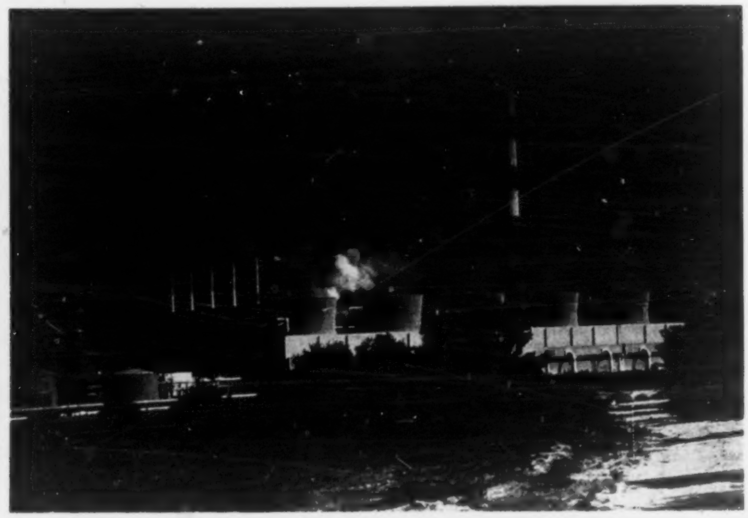
As a result, the phrase being used in the European industry more and more commonly is "industry cracker." Joint ventures, such as the Fife plant and Finaneste's cracker, seem likely to shape the future of the ethylene industry in Western Europe in the coming decade, as opposed to the U.S., where the concept of joint ventures has not yet progressed beyond the talk stage.

The pressures for joint-venture investment are becoming particularly persuasive. At least three factors are involved:

- The sheer cost of construction of a new cracker—at about $1000 per metric ton of capacity, works out to about $700 million for a 700,000 metric-ton-per-year ethylene cracker, the current upper level of "world scale."
- The recognized need for continuing consolidation within the industry in Western Europe. Capacity



DSM revamps ethylene furnaces at Netherlands plant



Shell's petrochemicals complex at Berre, France

itself has been slashed, from more than 18 million metric tons in 1980, to about 14.5 million now. However, the number of producers remains high. According to the Association of Petrochemicals Producers in Europe (APPE), one of the major sector groups within the European Chemical Industry Federation (CEFIC), there are 25 ethylene producers in Western Europe, compared with 21 in the U.S. and 11 in Japan. Moreover, Europe has a larger number of smaller operators than other major trading blocs; in the European market, the six largest producers account for 45% of production, compared with 55% in the U.S. and 50% in Japan.

- The fear of a resurgence of overcapacity from huge lumps of capacity coming onstream at the same time, swamping the market. In the Western European industry, which had serious problems of capacity underutilization and losses on ethylene in the first part of this decade, this fear is very much alive among senior managers, in particular, who had to make the subsequent painful decisions to cut or close cracker capacity.

In a way, closures of ethylene crackers in Western Europe have been made even more difficult because there are few isolated merchant crackers in Europe. Most crackers are part of integrated company petrochemical complexes, or are closely linked by pipeline to customers on long-term contract. And pipeline facilities are limited in Europe, where there are three distinct pipelines: one in the U.K., one in southern France, and the third in Benelux-West Germany.

The pipelines, which are open to all, are under capacity pressures just as constant as cracker capacity. The major pipeline in Benelux-West Germany, for example, operated by ARG (Aethylen Rohrleitungs Gesellschaft), jointly owned by the user partners, will be expanded by the beginning of next year. ARG is building a second ethylene pipeline to run alongside the existing line, increasing its grid length 18%, to cope with expansions planned by ethylene consumers in Belgium.

The most significant expansion of the three, in recent years, is in the U.K. Shell has sought permission from the British government to build a new pipeline from Grangemouth, Scotland, to its plants near Liverpool, England, in what would be a $150 million project scheduled for completion in early 1992. It would more than double ethylene carrying capacity from the ethane crackers in Scotland to derivatives plants in England's northwest. A new pipeline is especially needed, according to Shell, because demand is expected to exceed capacity of the existing pipeline by the early 1990s. Expansions in crackers along the route of the current pipeline will also add to the pressure.

The expansions that have been announced for the U.K. are just part of a spreading pattern of announcements throughout Western Europe. Companies are announcing new crackers, or major expansions of existing ones, as well as continuing to add incremental bits of capacity, through process improvements. At the same time, the management at various companies insist that the industry has learned its lesson, that it is not embarking on a round of overbuilding.

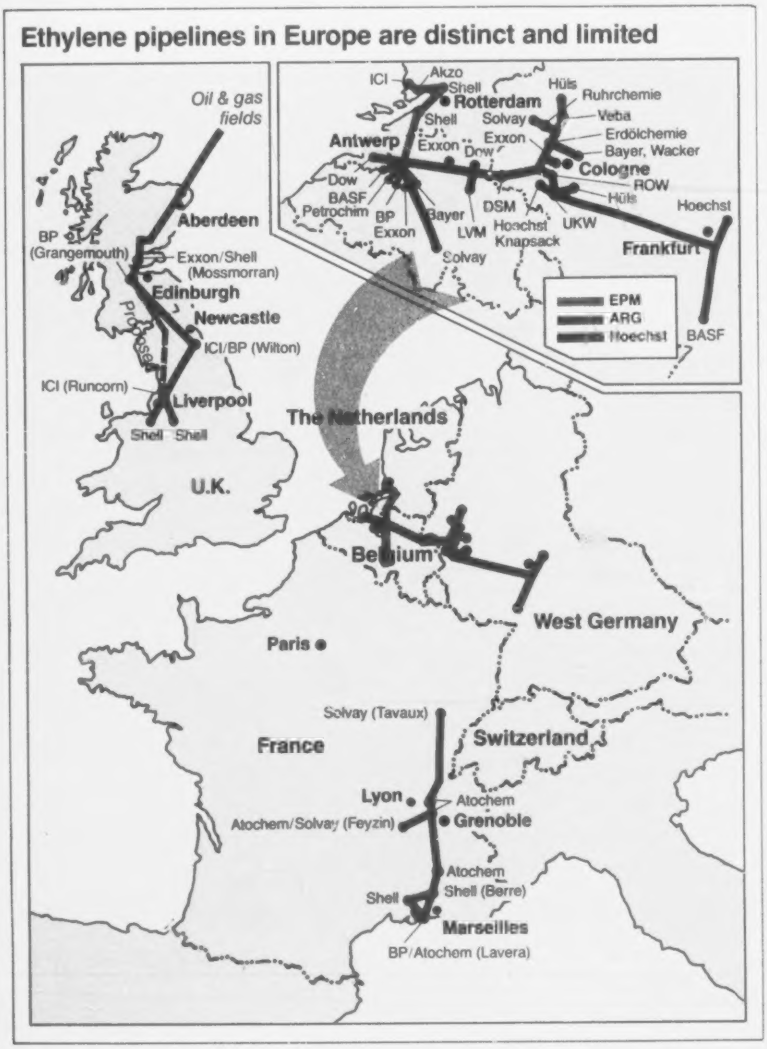
Some industry observers, however, have found worrisome signs in the host of announcements that have followed in the wake of crackers being run nearly flat out for the past year and a half. These observers fear that the Western European chemical industry will tumble headlong, once again, into the gloomy days of glut and loss.

"Average operating rates are at or close to a peak," noted David S. Glass, a director of Chem Systems International, at a petrochemicals conference in London in May. That can pose a potential problem. "Operating rates of over 90% are difficult to sustain for long periods due to maintenance closures, and the increasing likelihood of unplanned outages as plants are tested to the limit of their design capacity."

Chem Systems' work, he said, indicates that the margin for ethylene follows a relationship with operating rate that is more or less linear, up to about 90% capacity utilization—it then takes off exponentially. With the industry in that exponential region in the past two years, cracker operation contributed sound profits to the balance sheet.

Consequently, according to Glass, with the resultant cash generation from well-used plants, and plants at capacity, "the natural reaction is to spend on reinvestment."

Rising investment returns, in turn, have spurred interest in building new crackers from Enimont at Brindisi, Italy; Veba at Gelsenkirchen, West Germany;


Ethylene pipelines in Europe are distinct and limited

Oil & gas fields
Aberdeen
BP (Grangemouth)
Exxon/Shell (Mossmorran)
Edinburgh
Newcastle
Proposed
ICI/BP (Wilton)
ICI (Runcorn)
Liverpool
Shell
Shell
U.K.
ICI
Akzo
Shell
Rotterdam
Shell
Antwerp
Exxon
Dow
Exxon
Solvay
Hüls
Ruhrchemie
Veba
Erdölchemie
Bayer, Wacker
Cologne
ROW
Hüls
Dow
BASF
Petrochim
BP
Exxon
Bayer
LVM
DSM
Hoechst Knapsack
UKW
Hoechst
Frankfurt
Solvay
EPM
ARG
Hoechst
BASF
The Netherlands
Belgium
West Germany
Paris
France
Solvay (Tavaux)
Switzerland
Lyon
Atochem
Atochem/Solvay (Feyzin)
Grenoble
Atochem
Shell (Berre)
Shell
Marseilles
BP/Atochem (Lavera)

Repsol at Cartagena, Spain; Dow at Terneuzen, the Netherlands; Shell at Moerdijk, the Netherlands; and BASF at Antwerp, Belgium.

Moreover, Erdölchemie is restarting its second Dormagen cracker, ICI is considering the restart of its Wilton (U.K.) 5 cracker, and BP Chemicals has announced the doubling of capacity of its Grangemouth cracker. All of this adds up to more than 4 million metric tons of new capacity, disregarding expansions of existing units, according to Glass.

"It is clear that not all of these plans will see the light of day before 1995, if at all," he said. "But the trend is such as to take overall ethylene capacity from 15 million metric tons in 1989 to at least 19 million by 1995, possibly considerably more."

Already, some of the announcements are becoming less firm as market conditions soften. Although the slowdowns in demand and falling prices probably don't warrant the "free-fall" labels gloomily ladled out by some industry observers, they are distinct, nonetheless.

Neville B. Pinnington, vice president of Shell Chemicals International Trading Co. with responsibility for bulk petrochemicals, notes that "some of the products desperately tight have begun to turn," although, he adds, some perhaps have bottomed out and are starting back up again. "Demand is higher than it was a year ago, but not increasing as fast as it did a year ago."

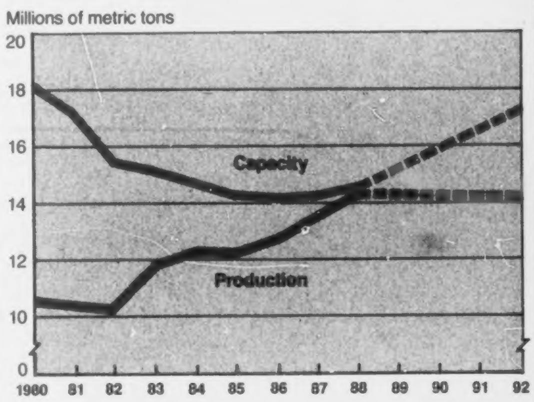
The drop in demand has led to a fall in prices for ethylene derivatives, such as polyethylene. For instance, the price of low-density polyethylene rose in the course of about two years from less than $600 per metric ton to more than $1200, but in the past six months, particularly at the end of the second quarter, has fallen off significantly. Indeed, according to one source, the spot price for LDPE toward the end of July was in the range of $780 to $850 per ton. However, prices have started to pick up again.

At the same time, the price of naphtha, the primary cracker feedstock in Western Europe, has begun going up. From well below $150 per metric ton for most of 1988, it moved up to about $170 per ton during the second quarter. And although prices slipped slightly in July, as demand went into a summer slack, they still are moving upward, following oil prices. A rise in feedstock prices and a decline in the prices for derivatives has begun to squeeze margins on ethylene, bringing a more realistic pattern into new-cracker thinking.

Most forecasters expect the demand for ethylene to grow at just over the growth rate of gross national product, perhaps at 2 to 3% a year. But even at a lower rate—a conservative 1.5%, say—an extra 225,000 metric tons will be needed each year. That, in turn, would be the equivalent of a major new cracker every two or three years, a capacity contribution that probably cannot be met even by industrywide process improvements and incremental expansions.

The uncertainty comes in how that capacity will be added, and who will add it. Most industry observers agree that, this time around, the announcements are in response to pressures within the company, from middle-level marketing managers who see a strategic need for companies to be self-sufficient.

That is different from the late 1970s and early 1980s, Ethylene capacity use is high



Source: Association of Petrochemicals Producers in Europe

when there was a decided "virility factor" of top executives having to have their own crackers, according to one analyst. It's not a question now of keeping up with the Joneses, although, says Shell's Pinnington, "If you are in a leading position, you don't want to give that up. If you get in amongst the leaders, that will discourage others. Therefore, there is an element of a race to this."

Most of the proposals have cited corporate need for the additions. For example, when BP Chemicals announced it was considering doubling the capacity at its Grangemouth cracker late last year, John Turnbull, chief executive for petrochemicals and polymers, pointed out that BP was already a net purchaser of ethylene. By 1992, the company predicted, its deficit would be 250,000 metric tons, and it could not accept that.

All the announcements thus far have made sense for each individual corporation, agrees Michael C. Cockburn, secretary general of APPE, but he is worried about overcapacity in the region. "I hear those denials, that companies say they have learned their lesson. But they haven't. The industry is staffed with people who are volume-hungry, brought up in the days when volume was king."

That was acceptable, he believes, when Western Europe was a major trading block. But that situation is changing rapidly. Ethylene itself may not be widely traded globally, but its derivatives are. Western Europe has long been one of the major derivatives-exporting countries, with product going in particular to the Far East and Eastern Europe. But countries there, eager to cut import bills, are starting to build up their own petrochemical industries.

The impact of Third World building has long been a concern, for example, of Stuart Wamsley, formerly senior chemicals analyst with Morgan Stanley International, and now a consultant and editor of a chemicals newsletter, *Focus on Chemicals*. According to Wamsley, the view that overcapacity will not happen—that growth rates remain too strong, and the Western World is building responsibly this time round—is too narrow and insular. In particular, he says, that view fails to take account of the huge capacities now emerging in developing nations.

According to figures he compiled for Morgan Stanley, areas of the world outside the U.S., Western Europe, and Japan have already built 9.5 million metric tons per year of ethylene capacity—two thirds that of Western Europe, and more than half that of the U.S. Planned additions between now and 1992 will add another 9.4 million metric tons, all to feed local derivatives plants. Other possible additions that have been reported could add yet another 21 million metric tons of capacity; current world capacity is 56 million metric tons. Local market supply—which could also serve export markets—will, in turn, cut into the market for Western European exports, hastening the decline in the continent's net trade of ethylene derivatives.

Some analysts believe that the industry also could avoid overcapacity by scrapping old cracker capacity as it builds new. Although crackers are continually being updated, says APPE's Cockburn, "there is a certain dating factor—you can see physically the difference in the building, for example, between a cracker of today compared with one from 1970. There are many more improvements you can bring in, rather than just debottlenecking."

However it controls ethylene capacity, the industry

Shell, Enimont are Europe's biggest ethylene producers

Thousands of metric tons	Capacity	Additions 1988–92	Other additions possible
Atochem	610[a]	100[a]	
BASF/ROW[b]	775		600
BP Chemicals	750[c]	290	
Dow	1,315	160	
DSM	925	100	
Enimont	1,455	560	50
Erdolchemie[d]	500	260	20
Exxon	665[e]	105[e]	15[e]
Finaneste[f]	550	450	
Huels/Veba	650	55	480
ICI	620[g]		
Naphtachimie[h]	500		50
Neste	530[i]		
Noretyl[j]	390	30	
OeMV	580		
Orkem	695		220
Repsol	595	115	
Shell/ROW[b]	1,475[e]	285[e]	135[e]
Statoil	350	70	
URBK	440	25	35
Others	225		100
TOTAL	**14,595**	**2605**	**1705**

a Includes 42.5% Solvay share in cracker, Feyzin, France. b 50-50 joint venture; ROW = Rheinische Olefinwerke. c Includes 20% share in ICI cracker, Wilton, U.K. d 50-50 joint venture, Bayer and BP Chemicals. e Includes 50% of Fife ethylene plant, Mossmorran, Scotland. f 65-35 joint venture, Petrofina and Neste. g 80% share of Wilton cracker. h 50-50 joint venture, Atochem and BP Chemicals. i Includes cracker at Sines, leased from Portuguese government. j 51-49 joint venture, Norsk Hydro and Statoil. **Sources:** Morgan Stanley International, company reports in Western Europe must wrestle with one other factor: the number of producers. Notes Cockburn, the number "has come down, but there is still more to do—there are too many. A number of producers of ethylene in Europe are uneconomic."

One of the major difficulties with consolidations is that there are few isolated merchant crackers in the continent. Most are part of an integrated petrochemicals and polymers complex. Deintegrating a cracker from a complex would be extremely difficult, although it can be done through asset swaps, for example, as has just happened with Enimont of Italy and Orkem of France at Orkem's Dunkirk cracker and petrochemicals complex.

There is also the question of obtaining approval of consolidation or rationalization from the regulatory authorities in the European Community. The specific trade authorities are in D-G IV, one of 20 directorates general making up the European Commission. D-G IV is charged with competition policy, with part of its charter akin to U.S. government antitrust units.

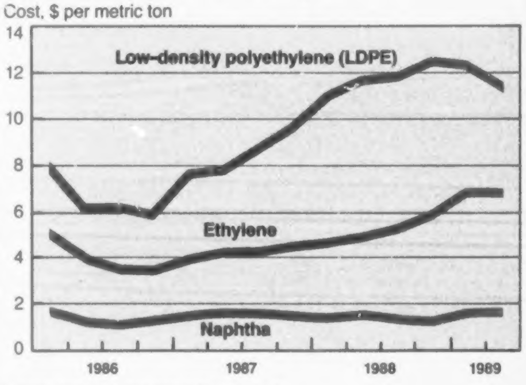
Thus far, there has been slow but steady success by the industry in obtaining clearance for its swaps or joint ventures. But the industry is keeping a close eye on the new direction D-G IV appears to be taking: At a petrochemicals conference in London last month, a representative of D-G IV said, in effect, that it had been generous with the chemical industry, but that this would not necessarily continue.

Says Jack G. Helfenstein, Dow Europe's executive vice president for hydrocarbons and materials management, "What we see happening is the industry cracker, owned or operated with a commitment from more than one company. We are exploring that for the Terneuzen expansion.

"The EC rules allow manufacturing joint ventures. You cannot have, without dispensation, a marketing joint venture. However, providing there is no coordination of ambitions and activities in marketing, and no constraints, you can combine to manufacture."

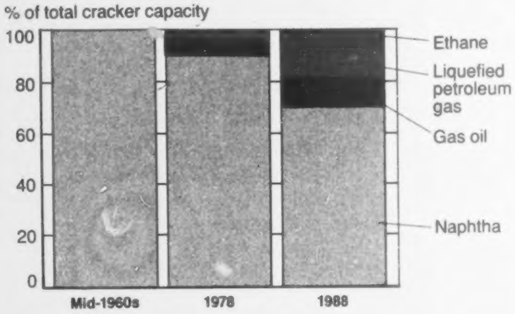
With such a venture, he adds, there would be "nothing to stop companies, then, to get economies of scale, new technology, whatever, through joint ventures in Europe. But the EC has to be assured that the cooperation is not beyond that. The chances are that one company will be the manufacturer, with two or three associated with the venture, in securing the off-take. There are various ways you can absolutely commit," without committing capital budgets, he says. "I think there will be that."

Naphtha price up, LDPE's down, squeezing ethylene margins



Source: Averages taken from published reports

Naphtha continues to dominate cracker feedstocks, but its share is smaller



Source: Association of Petrochemicals Producers in Europe

The idea of an "industry cracker" is also one that Shell's Pinnington would agree with. Such a venture, he says, would be a sensible way of spreading investment risk, and avoiding market disruption from several batches of capacity coming on stream at once.

"The thing that worries us is that people have become used to derivatives plants being fully loaded," he says. "So if someone says, 'I'm going to build a 200,000 metric-ton-per-year polyethylene plant, therefore I want a 200,000-metric-ton cracker,' he's forgetting that it doesn't happen from 'year one'. Those plants normally take some years to build up; there is some danger of overestimating the growth of the derivatives."

There is no question, he adds, that the EC and D-G IV "are taking a very close look at the chemical industry. They want to put as many teeth in their competition policy as they can. They undoubtedly would look very closely if the industry would come up with a set of joint ventures in ethylene; we would have to answer a lot of questions."

However, for purely manufacturing joint ventures, in which each company determines its own product slate and makes its own third-party contracts, although the companies would have to justify the venture, there is precedent—the Mossmorran plant, for example, operated by Exxon, but with Shell taking 50% of the output.

Joint ventures, coupled with the hard reflection that falling margins bring, may just carry Western Europe into the 1990s without a great sweep of overcapacity. □

Chemical Earnings Up Only Slightly in Second Quarter

William J. Storck,
C&EN Northeast News Bureau

The U.S. chemical earnings boom has turned into a pop. After years of running up phenomenal double-digit earnings growth in each successive quarter, U.S. chemical companies managed only 3% growth in this year's second quarter, compared with a year earlier. Small as that growth was, other chemical-producing companies did not fare well during the quarter. As a group, oil companies that also make chemicals posted a 3% decline in earnings, and chemical-producing diversified companies averaged only a slight 1% earnings gain. Only drug companies beat the chemical companies' increase, with an 8% gain.

The 3% growth for the chemical companies is the first time that earnings growth has been out of the double-digit range since the first quarter of 1986 and is the lowest since the fourth quarter of 1985 when the 30 chemical companies regularly surveyed by C&EN showed a decline in quarterly earnings results. At times, earnings growth was nothing short of phenomenal, averaging more than 50% and almost doubling in one quarter.

The gross fundamentals were still good in the second quarter. Chemical production for the quarter, according to government figures, was up about 6% from last year's second quarter. And chemical prices were up about 9%. Both of these measures slowed slightly from previous quarters, but they are still good by most standards.

However, the problems came in some markets and in some internal factors in the industry. Automobiles and construction, two key markets

Chemical industry leaders for the second quarter . . .

Sales				Earnings[a]			Profitability		
Rank 1989		$ Millions	Rank 1988		$ Millions	Rank 1988		Earnings as % of sales	Rank 1988
1	Dow Chemical	$4601.0	1	Dow Chemical	$728.0	1	International Flavors	17.4%	4
2	Monsanto	2348.0	2	Monsanto	241.0	2	Vista Chemical	17.3	7
3	Union Carbide	2277.0	3	Union Carbide	186.0	3	Georgia Gulf	16.9	3
4	W. R. Grace	1510.7	4	Arco Chemical	120.0	4	Arco Chemical	16.5	1
5	American Cyanamid	1299.3	5	American Cyanamid	110.4	5	Great Lakes Chemical	16.2	2
6	Hercules	791.5	6	Rohm & Haas	69.3	7	Dow Chemical	15.8	5
7	Rohm & Haas	735.2	7	Ethyl	57.6	9	Loctite	13.3	10
8	Arco Chemical	726.0	8	Air Products	53.4	11	International Minerals	11.3	12
9	Quantum Chemical	672.5	9	B. F. Goodrich	53.0	10	Nalco Chemical	11.1	15
10	Air Products	663.7	10	Georgia Gulf	49.3	12	Betz Laboratories	10.8	14

. . . and for the first six months of 1989

Sales				Earnings[a]			Profitability		
Rank 1989		$ Millions	Rank 1988		$ Millions	Rank 1988		Earnings as % of sales	Rank 1988
1	Dow Chemical	$9086.0	1	Dow Chemical	$1471.0	1	Great Lakes Chemical	17.7%	2
2	Monsanto	4613.0	2	Monsanto	463.0	2	International Flavors	17.2	5
3	Union Carbide	4518.0	3	Union Carbide	387.0	3	Georgia Gulf	17.2	3
4	W. R. Grace	2907.9	4	Arco Chemical	236.0	4	Vista Chemical	16.9	6
5	American Cyanamid	2530.9	5	American Cyanamid	199.4	5	Arco Chemical	16.6	1
6	Hercules	1530.9	7	Rohm & Haas	122.4	7	Dow Chemical	16.2	7
7	Quantum Chemical	1486.6	6	Quantum Chemical	117.4	6	Loctite	12.7	10
8	Arco Chemical	1425.0	9	Ethyl	114.0	8	Betz Laboratories	10.7	10
9	Rohm & Haas	1414.7	8	Air Products	110.0	9	Nalco Chemical	10.6	12
10	Air Products	1332.7	10	B. F. Goodrich	105.3	10	Ethyl	10.4	9

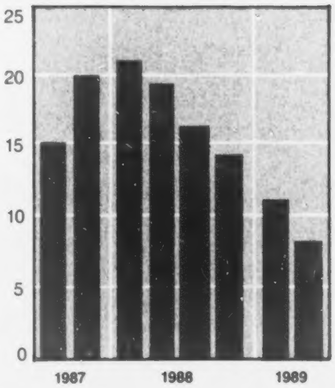
Note: Based on 30 chemical companies listed on page 16. a After taxes.

Chemical industry second-quarter 1989 results

- Sales increased 8%
- Earnings gained 3%
- Profit margins at 10%
- Production rose 6%
- Prices climbed 9%

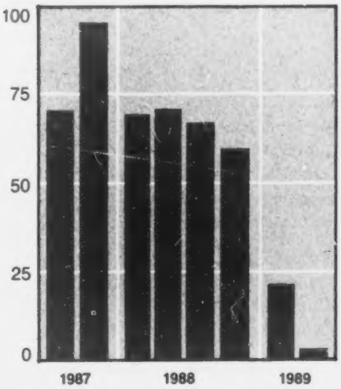
Sales

% change from year-earlier quarter



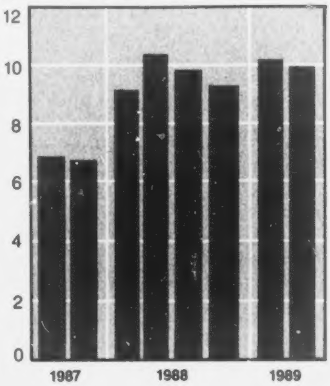
Earnings

% change from year-earlier quarter



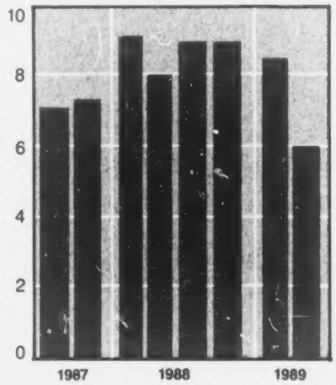
Profit margins

After-tax earnings as % of sales



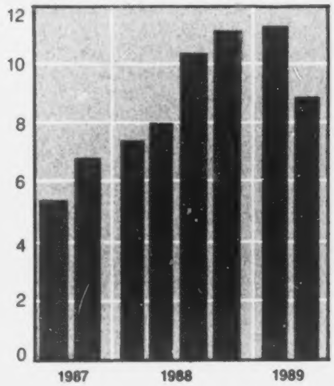
Production

% change from year-earlier quarter



Prices

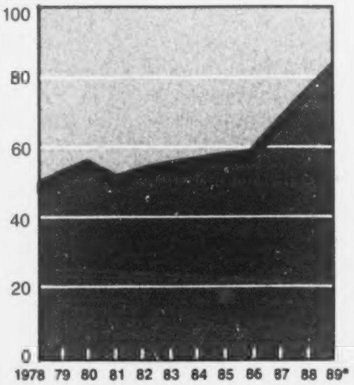
% change from year-earlier quarter



Sales in 1989 will increase about 8%, as earnings also grow about 8%, leaving profit margins at 9.8%

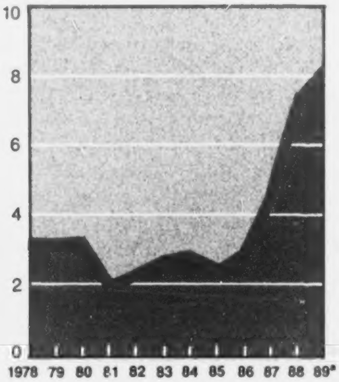
Annual sales

$ Billions



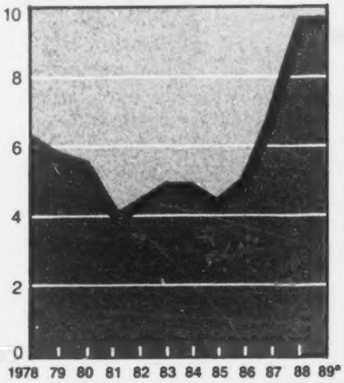
Annual earnings

$ Billions



Annual profit margins

After-tax earnings as % of sales



Note: All sales, earnings, and profit margin data are based on combined results of 30 chemical companies listed on page 16. a C&EN estimates.

Second-quarter earnings declined at a third of leading chemical companies

	SECOND-QUARTER 1989						FIRST-HALF 1989			
	Sales	Earnings[a]	Change from 1988		Profit margin[b]		Sales	Earnings[a]	Change from 1988	
	($ millions)		Sales	Earnings	1989	1988	($ millions)		Sales	Earnings
Air Products[c]	$ 663.7	$ 53.4	10%	2%	8.0%	8.6%	$ 1,332.7	$ 110.0	9%	2%
American Cyanamid[c]	1,299.3	110.4	4	11	8.5	8.0	2,530.9	199.4	6	12
Arco Chemical[c]	726.0	120.0	7	−5	16.5	18.6	1,425.0	236.0	13	1
Aristech	268.2	18.6	0	−47	6.9	13.2	543.4	45.1	3	−49
Betz Laboratories	130.4	14.1	17	17	10.8	10.8	254.8	27.2	17	17
Cabot[c]	470.5	9.6	11	−42	2.0	3.9	1,011.4	38.6	14	10
Chemed	151.1	7.2	40	19	4.8	5.6	293.0	12.6	41	18
Crompton & Knowles	95.0	7.3	39	47	7.7	7.3	182.8	12.7	47	45
Dow Chemical[c]	4,601.0	728.0	8	14	15.8	15.0	9,086.0	1471.0	10	29
Ethyl[c]	555.0	57.6	12	1	10.4	11.5	1.091.0	114.0	12	4
First Mississippi	137.0	−2.6	51	def	def	14.9	255.2	6.0	67	−56
H. B. Fuller	196.3	4.9	14	−14	2.5	3.3	373.9	6.8	14	−35
Georgia Gulf	292.3	49.3	6	4	16.9	17.2	610.0	104.7	22	22
B. F. Goodrich[c]	628.8	53.0	8	−7	8.4	9.7	1,244.7	105.3	12	8
W. R. Grace[c]	1,510.7	44.6	4	−23	3.0	4.0	2,907.9	74.9	6	−13
Great Lakes Chemical	192.3	31.2	40	25	16.2	18.2	337.4	59.8	22	22
Hercules[c]	791.5	41.6	12	−12	5.3	6.7	1,530.9	86.4	12	−1
International Flavors	236.8	41.3	1	6	17.4	16.6	464.0	80.0	1	7
International Minerals	265.9	30.0	1	1	11.3	11.3	524.3	52.4	6	0
Loctite	120.9	16.1	9	25	13.3	11.7	237.3	30.2	8	29
Lubrizol	325.6	26.0	14	17	8.0	7.8	668.8	56.7	16	23
Monsanto[c]	2,348.0	241.0	4	10	10.3	9.7	4,613.0	463.0	5	8
Nalco Chemical	268.1	29.7	8	14	11.1	10.5	517.6	54.8	7	7
Olin[c]	658.0	35.0	14	21	5.3	5.0	1,300.0	69.0	16	19
Petrolite	71.9	2.2	−5	−40	3.1	4.9	144.3	5.3	−6	−37
Quantum Chemical[c]	672.5	46.0	4	−42	6.8	12.2	1,486.6	117.4	7	−33
Rohm & Haas[c]	735.2	69.3	5	−9	9.4	10.8	1,414.7	122.4	7	−11
Union Carbide[c]	2,277.0	186.0	7	−1	8.2	8.8	4,518.0	387.0	11	34
Vista Chemical	202.3	35.1	7	26	17.3	14.7	400.8	67.6	−1	7
Witco[c]	413.4	23.2	2	2	5.6	5.6	813.0	43.5	2	39
Total 15 larger companies	**$18,350.6**	**$1818.6**	7%	3%	**9.9%**	10.3%	**$36,305.7**	**$3637.9**	9%	14%
Total 15 smaller companies	**$ 2,954.1**	**$ 310.5**	12%	0%	10.5%	11.8%	**$ 5,807.5**	**$ 622.0**	13%	2%
GRAND TOTAL	**$21,304.7**	**$2129.1**	8%	3%	10.0%	10.5%	**$42,113.2**	**$4259.9**	10%	12%

a After-tax earnings from continuing operations, excluding significant nonrecurring and extraordinary items. b After-tax earnings as a percentage of sales. c One of the 15 largest companies.

for the chemical industry, have been slowed by higher interest rates, a problem that may be easing as the Federal Reserve Board loosens credit to sustain the economy in an attempt to avoid a recession.

Maintenance itself has cut into sales and profits in some product areas as companies shut down plants, reducing the amount of product they had to sell. This problem was made worse in some instances by slow deliveries of materials needed for maintenance.

Raw material costs also climbed for some companies, cutting into profits. Firms using ethylene have been hit during recent months as plant outages and maintenance downtimes have cut supply, causing prices to rise. This situation abated somewhat in July boding well for the third quarter.

Also, foreign earnings have suffered at chemical companies. Although exports have generally held up, the currency translation has cut into earnings because of the stronger dollar as compared with other currencies. This has hampered earnings from foreign operations, even though volumes have not suffered.

Although chemical earnings averaged only a 3% rise, individual company performances during the quarter ranged from decline into deficit at ammonia-plagued First Mississippi to an increase of 47% at Crompton & Knowles. Of the 30 companies, 12 posted earnings declines. Of the 18 that showed improvement, four were below the 3% average. However, 12 of the companies still showed double-digit earnings growth in the quarter.

The 3% growth at the 30 chemical companies surveyed lifted earnings to a total of $2.13 billion. Sales during the period rose 8% to $21.3 billion, giving a profit margin of 10.0%. This profitability measure is slightly less than the 10.5% for last year's second quarter.

The difference in performance between the large and small companies was readily apparent in the second quarter. For the 15 larger

FIRST-HALF 1989		12-MONTH RUNNING DATA			
Profit margin[b]		Change from 1988		Profit margin[b]	
1989	1988	Sales	Earnings	1989	1988
8.3%	8.8%	10%	9%	8.5%	8.6%
7.9	7.5	6	11	6.9	6.6
16.6	18.6	26	33	17.3	16.4
8.3	16.6	7	34	12.2	9.7
10.7	10.7	16	19	10.8	10.5
3.8	3.9	17	11	3.5	3.6
4.3	5.1	43	7	3.9	5.2
6.9	7.0	39	44	5.8	5.6
16.2	13.9	16	50	15.6	12.0
10.4	11.3	23	12	10.1	11.1
2.3	8.8	36	−30	3.8	7.4
1.8	3.2	15	−32	2.4	4.0
17.2	17.3	34	42	18.1	17.0
8.5	8.8	8	68	9.0	5.8
2.6	3.1	16	−5	3.0	3.7
17.7	17.7	17	41	18.5	15.4
5.6	6.4	8	−28	4.6	6.9
17.2	16.3	2	9	15.8	14.9
10.0	10.6	−29	−26	8.0	7.7
12.7	10.7	9	30	11.9	10.0
8.5	8.0	14	33	8.5	7.3
10.0	9.8	5	9	7.3	7.1
10.6	10.6	10	18	10.7	10.0
5.3	5.2	18	23	4.4	4.2
3.7	5.5	−4	−37	3.4	5.2
7.9	12.5	6	21	10.8	9.5
8.7	10.4	10	0	8.2	8.9
8.6	7.1	15	113	9.3	5.0
16.9	15.7	6	23	16.7	14.3
5.4	3.9	4	3	5.1	5.1
10.0%	**9.6%**	**11%**	**33%**	**9.5%**	**7.9%**
10.7%	**11.9%**	**20%**	**26%**	**12.3%**	**11.7%**
10.1%	**9.9%**	**12%**	**31%**	**9.9%**	**8.4%**

def = deficit.

firms, earnings rose 3% to $1.82 billion on a 7% sales increase to $18.4 billion. Profit margins for the 15 larger companies averaged 9.9%, a drop from the 10.3% average in second-quarter 1988.

For the 15 smaller companies, earnings remained close to last year's second-quarter level, at $311 million, although sales increased 12% to $2.95 billion. As a result, the average profit margin for this group was 10.5%, down 1.3 percentage points from second-quarter 1988's average profit margin of 11.8%.

For the first half, combined earnings for the 30 companies rose 12% from first-half 1988 to $4.26 billion on a 10% sales gain to $42.1 billion. Profit margins averaged 10.1% up from 9.9% in first-half 1988.

Earnings for the first half for the group of 15 larger companies grew 14% to $3.64 billion on a sales growth of 9% to $36.3 billion. Profit margins for this group increased to 10.0% from 9.6% in first-half 1988. For the 15 smaller companies, earnings increased only 2% to $622 million, but sales increased 13% to $5.81 billion. The average profit margin for this group fell to 10.7% from 11.9% a year earlier.

Second-quarter earnings for the 30 companies were essentially unchanged from the first quarter, but sales were up 2.4%. Earnings were flat for both larger and smaller firms, but the smaller firms beat out the larger ones in sales growth at 3.5%, compared with 2.2%.

While overall earnings for chemical firms were increasing only slightly during the second quarter, chemical earnings rose substantially for oil companies. A group of six oil companies—Chevron, Exxon, Mobil, Occidental, Shell, and Texaco—posted total chemical earnings of $1.16 billion for the quarter, up 23% from the same period last year. Considering that oil companies generally had a poor quarter for earnings, chemical results added considerably to the bottom line. Occidental's chemical earnings include Cain Chemical for only part of the period last year, making the comparison somewhat cloudy, but even when Occidental is excluded, the earnings for the remaining five firms increased 18%. For the six months, chemical earnings at the six oil companies were up 38% to $2.49 billion. Even without Occidental, earnings increased 30%.

Despite the modest overall earnings performance, individually most chemical company executives remain upbeat.

For Dow Chemical, the largest chemical company among the 30, financial vice president Enrique C. Falla says, "Overall volume continues strong, and, with the exception of polyethylene, prices remain stable. Margins at historic highs reflected the impact of flat prices and slightly increased costs versus previous quarters. Sales volume and supply/demand fundamentals remain strong globally."

"Outstanding" was the way Monsanto's chairman and chief executive officer Richard J. Mahoney characterized the company's second-quarter performance. Monsanto saw improvement in operating earnings in all of its units except NutraSweet.

Plastics were a problem at some companies. For instance, Robert D. Kennedy, Union Carbide's chairman, said that polyethylene prices have softened since the first quarter. But he noted that raw material

Ground rules for C&EN earnings analysis

C&EN's quarterly report on financial performance of the U.S. chemical industry contains data from the 30 largest U.S. basic chemical companies and from 24 oil and diversified companies, each with more than $200 million in annual chemical sales, plus 11 pharmaceutical companies.

To be included in the table of basic chemical producers, a company must have at least 50% of its sales in chemicals. That is why Du Pont, for example, is included in the table of diversified manufacturers.

In referring to chemical sales, C&EN means those chemicals whose molecular composition has been changed in the course of manufacture. Hence, chemical sales include those of traditional categories of basic petrochemicals and inorganics, organic intermediates and inorganic compounds, polymers such as plastics and fibers, and agricultural chemicals and specialty derivatives.

In listing earnings, the survey gives after-tax income for continuing operations before nonrecurring items and extraordinary charges. Foreign currency translations are included.

Earnings declines are spreading to oil, diversified, and drug firms

	SECOND-QUARTER 1989						FIRST-HALF 1989					
	Sales	Earnings[a]	Change from 1988		Profit margin[b]		Sales	Earnings[a]	Change from 1988		Profit margin[b]	
	($ millions)		Sales	Earnings	1989	1988	($ millions)		Sales	Earnings	1989	1988
OIL AND GAS COMPANIES												
American Petrofina	$ 847.4	$ 41.8	29%	22%	4.9%	5.2%	$ 1,566.3	$ 90.6	24%	40%	5.8%	5.1%
Amoco	6,078.0	497.0	13	−25	8.2	12.3	11,989.0	955.0	14	−16	8.0	10.8
Ashland	2,093.8	43.5	3	−24	2.1	2.8	3,993.8	38.5	2	−51	1.0	2.0
Chevron	8,200.0	392.0	12	14	4.8	4.7	15,900.0	705.0	7	−12	4.4	5.4
Exxon	23,611.0	1010.0	9	−16	4.3	5.5	45,855.0	2310.0	5	−13	5.0	6.1
Kerr-McGee	821.2	35.1	17	20	4.3	4.2	1,538.3	69.0	13	74	4.5	2.9
Mobil	14,003.0	541.0	0	4	3.9	3.7	28,023.0	970.0	1	−9	3.5	3.8
Occidental Petroleum	5,050.0	84.0	6	−3	1.7	1.8	10,193.0	150.0	11	3	1.5	1.6
Phillips Petroleum	3,299.0	197.0	15	16	6.0	5.9	6,401.0	387.0	11	29	6.0	5.2
Shell Oil	6,291.0	440.0	8	61	7.0	4.7	11,860.0	801.0	5	28	6.8	5.6
Sun Co.	2,920.0	105.0	20	9	3.6	4.0	5,560.0	186.0	15	19	3.3	3.2
Texaco	8,449.0	366.0	−9	−21	4.3	5.0	18,059.0	631.0	0	−14	3.5	4.1
Unocal	3,078.0	120.0	20	88	3.9	2.5	5,715.0	207.0	17	92	3.6	2.2
DIVERSIFIED MANUFACTURERS												
Allied-Signal	3,115.0	143.0	1	12	4.6	4.1	6,057.0	269.0	0	12	4.4	4.0
Du Pont	9,278.0	714.0	11	12	7.7	7.7	17,952.0	1450.0	11	18	8.1	7.6
Eastman Kodak	4,500.0	287.0	9	−26	6.4	9.4	8,400.0	487.0	13	−25	5.8	8.7
Engelhard	603.1	15.1	14	7	2.5	2.7	1,190.3	29.5	14	7	2.5	2.6
FMC	917.1	55.6	3	47	6.1	4.2	1,754.2	89.6	9	45	5.1	3.9
Ferro Corp.	275.5	13.2	6	11	4.8	4.6	546.9	25.5	9	11	4.7	4.6
3M	3,025.0	327.0	4	6	10.8	10.6	6,042.0	645.0	6	10	10.7	10.3
NL Industries	268.5	41.1	0	10	15.3	14.0	512.0	83.8	−2	24	16.4	12.9
PPG Industries	1,490.0	127.3	3	−5	8.5	9.2	2,950.0	257.1	5	2	8.7	9.0
Tyler	110.2	3.5	13	0	3.1	3.5	200.6	1.5	11	−61	0.8	2.2
Vulcan Materials	293.7	43.6	3	−5	14.8	16.2	511.2	59.2	5	−4	11.6	12.6
PHARMACEUTICAL COMPANIES												
American Home Products	1,400.7	236.4	2	10	16.9	15.7	2,920.6	500.5	5	11	17.1	16.3
Baxter Travenol	1,856.0	104.0	10	14	5.6	5.4	3,630.0	205.0	12	13	5.6	5.6
Becton Dickinson	442.8	39.0	1	−2	8.8	9.0	905.7	80.6	4	6	8.9	8.7
Bristol-Myers	1,534.5	212.5	5	12	13.8	13.1	3,136.7	449.6	5	12	14.3	13.5
Merck	1,585.2	396.6	6	25	25.0	21.1	3,156.6	737.0	7	25	23.3	20.0
Pfizer	1,302.7	135.7	−3	−36	10.4	15.9	2,739.0	376.5	4	−13	13.7	16.4
A. H. Robins	187.2	2.8	−2	−68	1.5	4.6	414.1	19.1	1	−18	4.6	5.7
Schering-Plough	805.5	120.5	7	19	15.0	13.4	1,637.3	246.2	9	22	15.0	13.5
SmithKline Beckman	1,255.5	118.6	10	20	9.4	8.7	2,497.3	248.8	9	−6	10.0	11.5
Upjohn	736.5	94.6	2	8	12.8	12.2	1,491.6	197.6	8	8	13.2	13.2
Warner Lambert	1,024.7	112.4	8	23	11.0	9.6	2,044.4	213.4	9	22	10.4	9.3

a After-tax earnings from continuing operations, excluding significant extraordinary and nonrecurring items. b After-tax earnings as a percentage of sales.

costs were still favorable. And Goodrich's Geon vinyl products segment reported operating income of $57.3 million in the second quarter, down from $62.1 million in the same period last year.

Aristech complained of continued compression of polypropylene margins. Despite improved volume, the company says, "soft pricing for the product, resulting from increased capacity and an unsettled export market, as well as increased raw material costs, had a significant comparative negative impact."

The export market affected many other companies as well. Rohm & Haas chairman J. Lawrence Wilson says "Second-quarter earnings were influenced strongly by external economic trends. Sales growth in the plastics and industrial chemicals business was affected adversely by slowing in segments of the U.S. and European economies; European and Pacific region earnings were hurt by the continuing weakening of the major European currencies and the Japanese yen; and margins were squeezed by higher raw material costs and inflation."

Cabot estimates that currency fluctuations reduced earnings by about

$11 million for the quarter. W. R. Grace notes a "severe currency devaluation in Argentina" as having a negative impact on its earnings.

Grace also notes that most factors that affected the second-quarter performance are not expected to continue over the remainder of the year.

It is this that makes the rest of the year so difficult to predict. If credit policy is eased, consumers may be more likely to reenter the housing market and to buy big-ticket items such as automobiles. Although some currency fluctuation may persist, it is hoped that the Latin American devaluations that have been harmful are over.

Companies are hoping that the outside influences that cut earnings growth to less than that of sales will be halted in the third and fourth quarters. Supporting this, Olin chairman John W. Johnstone Jr. remarks, "Given a stable economy, I believe Olin is in a good position to attain its 1989 objective of $6.00 per share in earnings." This, however, may include some economic slowing since the company earned $3.37 in the first half, leaving it with only $2.63 to achieve its goal.

Dow's Falla says that "even in light of a softened U.S. economy and a stronger dollar, Dow's overall business outlook remains bright. We are very pleased with the second-quarter results and we continue to be confident in our performance for the balance of the year."

Outside observers are not so sanguine, however. An economic forum convened by the Conference Board, the New York City-based business research organization, says that in the overall economy, the outlook for profits is cloudy. But for the chemical industry, the forum participants, 15 economic analysts in government, industry, and finance, say that the outlook is middling. They say that the upswing in chemical profits is coming to an end sooner than expected. The pricing environment has softened, and costs continue to creep up. Earnings could drop sharply, the forum says, if operating rates fall widely. "While this is likely only for a few products," the Board says, "unless export demand stays strong, the profits outlook is mediocre." ☐

Startup firm profits from sulfite bans

As the Food & Drug Administration (FDA) continues to limit or extend bans on sulfites used as food preservatives, one small company formed in February 1988 is offering alternatives based on proprietary blends of FDA-approved ingredients including citric acid, ascorbic acid, and sodium pyrophosphate.

Extended Product Life (EPL) president Scott Berger says the company's current focus is on providing a dry mix of ingredients that can be dissolved in water for application as a spray or dip to preserve fresh-cut apples, potatoes, and other fresh fruit and vegetables. The frozen, canned, and dehydrated food markets are even more promising, says Berger. The company estimates the total existing market for sulfite replacements is as large as $300 million annually.

EPL's sales for the fiscal year that ended April 1989 were about $32,000. Although it had a negative cash flow for the fiscal year, Berger says the company will break even next year with considerably higher sales.

Joe H. Cherry, who currently is the chairman of the botany and microbiology department at Auburn University, Auburn, Ala., says "other people's formulas depend on strong acids or heating. EPL's approach is to block enzymatic action and treat food as [living] tissue." Cherry developed EPL's patented formulas while at Purdue University.

Cherry holds a one-third interest in the company, which has its executive offices in Conshohocken, Pa., and which trades on the over-the-counter stock market.

The company's potential competitors include Monsanto, Pfizer, Hercules, and General Brands. EPL's Berger says his company's product should be viewed more as a "take-along" product that would enhance a packaging system's performance.

Marc Reisch

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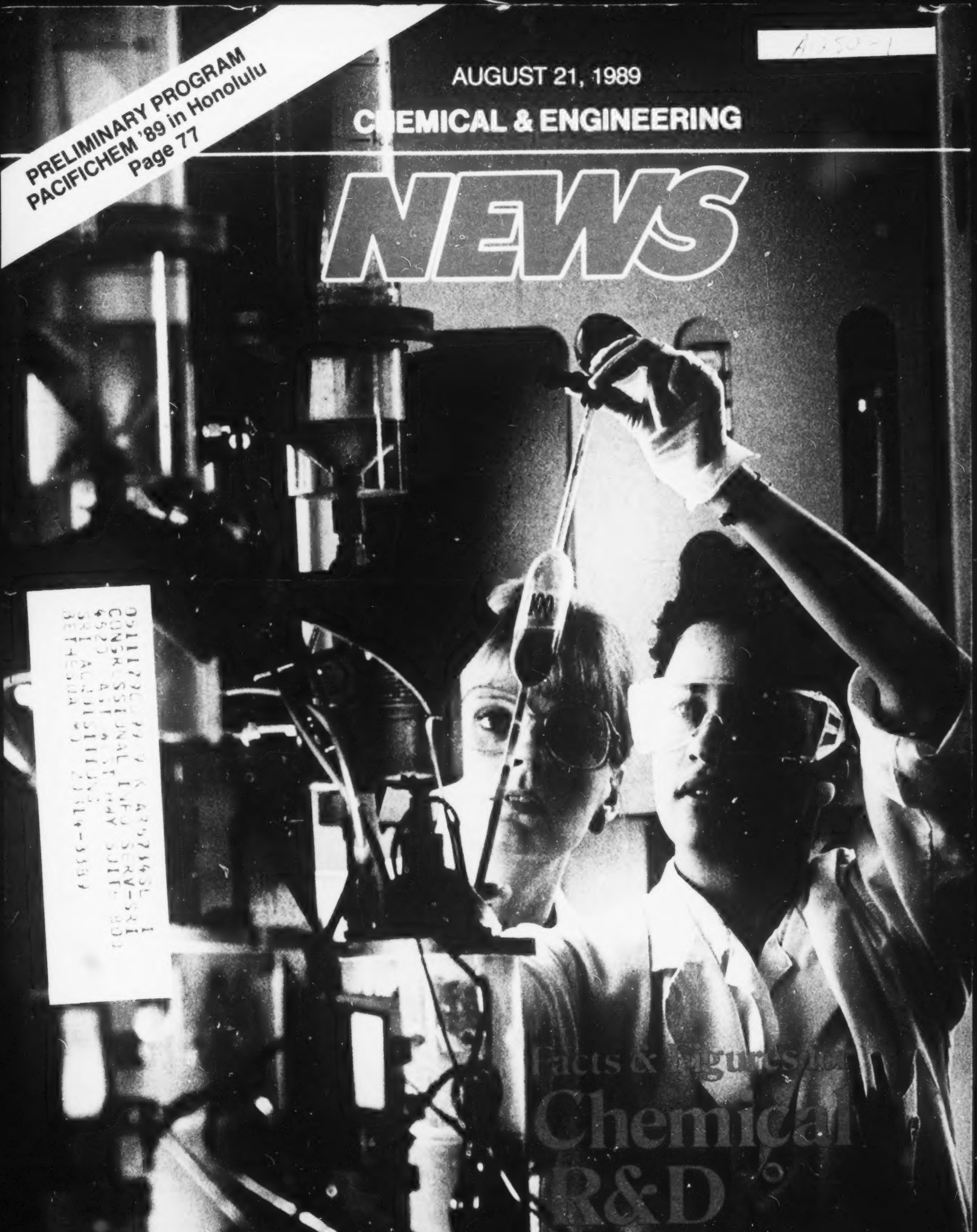
CHEMICAL & ENGINEERING NEWS



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Facts & Figures for
Chemical R&D
Page 28

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CHEMICAL & ENGINEERING NEWS

AUGUST 21, 1989

News of the Week

- **Evidence based on DNA profiling has been thrown out in a New York City murder trial, although the same judge also ruled that the technique can be used if performed and interpreted properly.** **Page 6**
- **Voyager 2 will reach Neptune this week to give first closeup glimpse of the outermost planet of the solar system.** **Page 7**
- **U.S., Soviets finish productive talks aimed at limiting size of underground nuclear arms tests; joint seismic research program is being expanded.** **Page 7**
- **New gasoline blend to be offered by Arco will replace leaded fuel, cut air pollution from older cars not equipped with catalytic converters.** **Page 8**

Cover: Photo courtesy of Air Products & Chemicals

Letters 4

Concentrates
Business 9
Government 14
Science/Technology 18

The Departments
Software/Database Update 23
New Products 27
People 71
Newscripts 100

Business

OxyChem plans new facility, enters agreement with Canadian firm as part of effort to expand in sodium chlorate market; New Jersey-based specialty chemicals maker, Epolin, to bring expanding monomers to market. **Page 10**

Government

Most federal agencies get R&D funding boost in House appropriation actions for fiscal 1990, but Defense gets cut. **Page 15**

Science/Technology

Fast atom bombardment technique combined with HPLC offers improved analysis of bile acids; temperature, other standards of measure to change as result of international agreement; computer firms lend hardware for use at ACS molecular modeling course. **Page 20**

Books

In **"Managing Technology: The Strategic View,"** Lowell W. Steele attempts to provide mind-set for the role of technology in a business framework. **Page 62**

ACS News

ACS Board approves 155 new or continuing Petroleum Research Fund grants totaling $4,106,471. **Page 66**

Preliminary Program

PACIFICHEM '89 in Honolulu, Dec. 17-22: list of symposia, advance registration form. **Page 77**

Facts & Figures for R&D

C&EN's annual compilation of statistics for chemical research and development shows steady, if modest, growth, with 1989 expenditures expected to top $145 billion. **Page 28**

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LETTERS

CHEMICAL SAFETY

Iodonium salt explosions

SIR: The current renaissance in polycoordinate iodine chemistry and in particular iodonium salt species, along with the recent report by G. v. Look (C&EN, July 24, page 2) on the explosion of iodosobenzene tetrafluoroborate, prompts us to report our own experiences with these compounds. We have also had an explosion (fortunately with no injury and only very minor damage) in the attempted preparation of an iodonium perchlorate, specifically $PhC{\equiv}C{-}I^+{-}Ph{\cdot}ClO_4^-$. In contrast, we have prepared numerous, diverse iodonium triflates and tosylates (up to 25 g scale), including $PhC{\equiv}C{-}I^+{-}Ph{\cdot}{}^-OTf({}^-OTs)$, and to date experienced no difficulties in the formation, handling, and subsequent transformations of these salts.

It is generally recognized that perchlorates tend to be explosive, whereas fluoroborates are much less explosive, and triflates are considered even more stable. Hence, we suggest the substitution of triflate ($CF_3SO_3^-$) for ClO_4^- in all cases where a nonnucleophilic counter ion is desired and perhaps even in some cases as substitution for BF_4^-. Even with triflates, ordinary caution should be exercised in the handling of all potentially explosive compounds—including the above and related polycoordinated iodine species.

Peter J. Stang
Professor of Chemistry
University of Utah

Environmental stewardship

SIR: I wonder how many caught the irony implicit in the Du Pont article on environmental stewardship (C&EN, May 29, page 12).

To start off, Edgar S. Woolard Jr. does a nice job of trying to torpedo Greenpeace and other proenvironment groups. But that's been the history of industry, both chemical and coal-stack, for too many years.

The real irony comes with Woolard's attempt to show how Du Pont is such a good guy regarding chlorofluorocarbons and ozone depletion. I well remember the almost strident tone that Du Pont took in trying very hard to refute any possibility that Mario Molina and F. Sherwood Rowland had correctly assessed the relation of CFCs and ozone. As he neatly points out, with an attempt at sugar coating, Du Pont was much more concerned with the dollars involved than with any possible environmental damage.

But this has been true in case after case in industry. The tobacco industry still claims that there is no proof connecting smoking with health damage, and they don't care how many people they kill as long as the profits keep rolling in (and do they ever).

The automobile industry fought tooth and nail against pollution control and safety restraints, and is still fighting to lower mileage requirements, which directly correlates to air pollution. Bigger engines gulp more gas (wasting more petroleum) and spew out more emissions, but the dollar profits on big engines in big cars far outweigh environmental considerations.

U.S. Steel fought aggressively to combat waste dumping controls, and thus effectively killed local marine environments around their plants. And they also fought against controlling smokestack emissions.

In summation, if you're going to have articles on environmental stewardship, maybe you should try to pick industry examples that are more meaningful than Du Pont.

Rubin Weiner
Hoffman Estates, Ill.

Cold fusion credibility

SIR: The controversy over cold fusion, which has been the subject of heated debates, newspaper editorials, and press conferences, has generated a lot of heat but very little fusion of ideas. Unfortunately, this whole episode has acquired a comic atmosphere. The strong sentiments expressed in C&EN (May 22, page 8) are an indication of the future exchanges between scientists on the two sides of this controversy.

A lingering controversy over theoretical concepts is understandable, but doubts about experimental results are unacceptable. The present situation has a historic parallel. The findings of Louis Pasteur in 1848 when he resolved sodium ammonium racemate, discovered L-tartaric acid, and laid the foundation of stereochemistry were considered extraordinary. The French Academy of Sciences requested an eminent scientist, Biot, to authenticate these results before the scientific community could accept them. Pasteur was invited to Biot's laboratory to demonstrate the accuracy of his results and all doubts were laid to rest.

Pasteur did not have to contend with patents, nor did universities use the lure of millions of dollars to guide scientific

House Completes Work on Funding Bills with Few Changes, Debates

Defense RDT&E cut but NSF and Public Health Service research funds increased in appropriation bills for federal agencies

Janice R. Long, C&EN Washington

The House completed work on all 13 of the appropriation bills needed to fund government activities in fiscal 1990, which begins Oct. 1, before Congress adjourned for its annual August recess. That was surprising in itself. Even more surprising was how few amendments were offered and how little debate was generated by these bills, which limit the amount of money that various federal departments and agencies can spend in any given fiscal year. Of the amendments offered, a number dealt with research and development matters.

For example, just three amendments were offered to the Department of Defense appropriation bill, H.R. 3072, one of which successfully deleted $10 million earmarked for the transverse-mounted engine system for armored vehicles from the Army's research, development, test, and evaluation (RDT&E) account. The House provided a total of $35.3 billion for DOD RDT&E programs in fiscal 1990. That's 5% below current spending levels and 10% less than the Administration had requested.

The Army's RDT&E budget is set at $5.6 billion, 9% above fiscal 1989 levels; the Navy's at $9.8 billion, up 4%; the Air Force's at $12.4 billion, down 14%; and that for the defense agencies at $7.5 billion, down 11%.

While cutting DOD's RDT&E budget, the House Appropriations Com-

NASA a big winner in House-approved 1990 R&D budgets

$ Millions	1990 Appropriation	1990 Request	1989	% difference Appropriation-request	% change 1989–90
Defense	$35,309.9	$39,495.4	$37,321.5	−10%	−5%
Tactical programs	12,635.2	14,595.9	13,168.7	−13	−4
Advanced technology development	5,149.9	6,623.2	5,896.8	−22	−13
Strategic programs	5,046.7	5,752.8	6,480.7	−12	−22
Intelligence and communication	4,950.5	4,763.7	4,499.1	4	10
Mission support	3,892.6	4,469.5	3,798.4	−13	2
Technology base	3,635.0	3,290.3	3,477.8	10	5
NIH	7,678.6	7,529.4	7,144.8	2	7
NASA	5,587.4	6,093.4	4,456.8	−8	25
Conduct of R&D	5,203.1	5,751.6	4,166.7	−10	25
R&D facilities	384.3	341.8	290.1	12	32
Energy	4,846.1	4,599.4	4,543.2	5	7
Energy supply R&D	**1,848.6**	**1,848.1**	**1,843.0**	**0**	**0**
Supporting research and technical analysis	690.7	671.4	642.2	3	8
Nuclear	577.5	590.3	610.5	−2	−5
Magnetic fusion	308.0	349.3	351.5	−12	−12
Other	147.8	112.5	147.8	31	0
Weapons R&D	**1,356.8**	**1,356.8**	**1,279.7**	**0**	**6**
General science and research	**1,062.4**	**1,169.4**	**922.1**	**−9**	**15**
Fossil R&D	**422.7**	**163.6**	**380.6**	**158**	**11**
Conservation R&D	**155.6**	**61.5**	**117.8**	**153**	**32**
NSF	1,999.0	2,149.2	1,922.5	−7	4
Research and related activities	1,715.0	1,803.2	1,620.5	−5	6
Science education activities	210.0	190.0	171.0	11	23
Antarctic programs	74.0	156.0	131.0	−53	−44
Commerce	1,067.8	1,016.8	1,359.7	5	−22
NOAA	966.9	849.3	1,091.7	14	−11
NIST[a]	na	155.6	159.0		
PTO	101.9	101.9	109.0	0	−7
USDA	1,088.9	1,028.8	1,045.1	6	4
Agricultural Research Service	591.5	581.1	563.4	2	5
Cooperative State Research Service	319.6	295.4	315.4	8	1
Forest Service research	149.4	133.8	137.9	12	8
Buildings and facilities	28.4	18.5	28.4	53	0
EPA R&D	431.0	421.5	386.5	2	12
TOTAL	$58,008.7	$62,333.9	$58,180.1	−7%	0%

Note: All numbers are estimates. a No funds provided for NIST because it lacks a 1990 authorization. na = not available.

mittee found room for lump-sum increases totaling $158 million for DOD's technology base programs that provide funds for basic research and which, as the committee noted, did not benefit from the rapid weapons system RDT&E increases that occurred between 1981 and 1985.

However, the committee went along with the Administration's decision to cut funding for university research sciences by over 30% to $96 million and cut an additional $27 million from the three armed services' budget requests for laboratory equipment. In its report on H.R. 3072, the committee cited a report by DOD's inspector general that found that up to 17,000 items of laboratory equipment valued at over $140 million are lost, stolen, missing, or not recorded in property records as one reason for reducing the laboratory equipment account.

The House appropriated a total of $12.6 billion for the Public Health Service in fiscal 1990. That amount is 7% above current funding and 2% more than requested. It includes about $1.6 billion for research, education, and other activities directed at prevention and treatment of acquired immune deficiency syndrome (AIDS). As the committee noted in its report on H.R. 2990, this represents an increase of about 25% of current spending on AIDS. However, it said, "the exact amount for AIDS-related biomedical research will be determined through the peer review system as applied by the various institutes at the National Institutes of Health and the Alcohol, Drug Abuse & Mental Health Administration."

Total funding for the National Institutes of Health was set at $7.7 billion, an increase of 7% over current funding and 2% over the Administration's budget request. The overwhelming majority of the individual institutes are slated for budget increases of 4 to 6%, barely enough to keep up with inflation. It's estimated that NIH will be able to fund only about 30% of the research proposals it will receive in fiscal 1990. The one exception is the National Institute of Allergy & Infectious Diseases, whose budget is up 14% to $845 million, just slightly over the amount requested.

The committee added $60 million to the budget request for NIH buildings and facilities; $44.4 million for biomedical research support grants; $34 million for a new supercomputer; and $32 million for high-priority extramural and intramural research projects. It deleted $38 million from the $100 million requested for the National Center for Human Genome Research, which still leaves the center with a 25% funding increase to $62 million.

The National Aeronautics & Space Administration was the biggest winner in R&D budget increases. The House gave it a 25% increase over current funding to $5.6 billion, and that's still 8% below what

Everything.

*Trademark of The Dow Chemical Company

the Administration wanted. The House provided $1.7 billion for the space station, $395 million less than requested. The Appropriations Committee admitted that the decrease may cause a slip in the scheduled March 1995 launch of the first element of the space station but said it had no alternative given the amount of money it had to work with in the Veterans Affairs, Housing & Urban Development, and Independent Agencies allocations.

The full House accepted two amendments to NASA's R&D budget offered by Rep. Robert A. Roe (D.-N.J.), chairman of the Science, Space & Technology Committee. One amendment earmarks $98 million for the national aerospace plane; the committee had allotted $78 million for it. Another Roe amendment struck language that would have allowed NASA to enter into a contract with California Institute of Technology for construction of the observational instruments laboratory at Jet Propulsion Laboratory for a total cost of not more than $14 million. Roe objected to the facility's not having been authorized by his committee.

For the Department of Energy's R&D programs, the House increased funding 7% above current levels to $4.8 billion. For research and related activities at the National Science Foundation, it increased funding 6% to $1.7 billion. And for the Department of Agriculture's research programs, it raised funding 4% to $1.1 billion (C&EN, July 31, page 5).

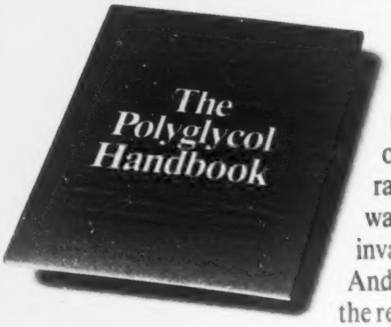
It's impossible to determine overall funding for the Department of Commerce's R&D programs at this time, because a fiscal 1990 authorization bill for the National Institute of Standards & Technology has yet to be enacted; thus no money can be appropriated by the House for NIST. The necessary legislation is expected to be ready for floor action soon after Congress returns on Sept. 6.

However, funding for the National Oceanic & Atmospheric Administration's operations, research, and facilities account, going counter to the trend for other nondefense R&D programs, is down 11% to $967 million. The Administration had been seeking a 22% cut. Funding for the Patent & Trademark Office is down 7% to $102 million, the requested level. However, the reduction in appropriated funds should be more than offset by increased patent and trademark fee collections.

Funding for the Environmental Protection Agency's R&D programs is up about 12% to $431 million. Funding for extramural research is up 19% to $242 million. Of that, up to $11.6 million can be used to purchase laboratory equipment.

By law, the Senate must wait for the House to act first on all appropriation bills. But if the Senate follows the House's example of speedy action on its appropriation bills, the federal government might start fiscal 1990 with a budget in place. □

From stop to bottom.



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Facts & Figures for Chemical R&D

Rebecca L. Rawls, C&EN Washington

"Steady as she goes" is an apt description of research and development in the U.S. as the 1980s draw to a close. The big increases in R&D spending from the federal government of five and six years ago, particularly for defense, have leveled off, leaving an R&D effort that is substantially larger than it was at the beginning of the decade, but also one that is growing more slowly.

Total spending on R&D will top $145 billion in 1989, C&EN estimates, a 6% rise over similar estimates for 1988. That would make 1989 the fourth year running to post a 6% gain in overall R&D outlays in the U.S. This year's growth is down from the 14 and 15% gains made in some years early in the decade. Still, it represents steady, if unspectacular, growth.

The difference between the early 1980s and the past few years is less when inflation is taken into account. At its present relatively low 3 to 4% per year level, inflation accounts for about half the growth in overall R&D dollars experienced from 1986 through 1989. Early in the decade, inflation was as high as 10% per year and claimed a bigger share of R&D's year-to-year growth. It whittled 1981's 15% rise in R&D spending down to only a 5% gain in inflation-adjusted dollars, for example. That 5% increase is the rate at which overall R&D was growing each year a decade ago, after adjusting for inflation. For a brief time from 1983 to 1985, big increases in defense-related R&D pushed real growth in R&D in the U.S. as high as 10% per year. Thus, the present 3%-per-year, inflation-adjusted increase (since 1986) is noticeably less than the growth that was taking place earlier in the decade.

Another shift has occurred during the past decade. The fraction of the total R&D effort that is defense-related has increased. Ten years ago defense-related R&D made up 23% of the total. Its share climbed rapidly in the early Reagan years to reach 34% by 1987. It now has dropped back to about 31%. Dollar-for-dollar, defense R&D benefits the civilian economy less than other types of R&D, so not only are present R&D budgets growing more slowly than a decade ago, but their long-term beneficial effects on the economy as a whole are likely to be smaller as well.

1 Overview

Where R&D funds come from and who performs the work. Who gets U.S. chemical patents and in what fields papers are published.............33

2 Federal Government

Spending for R&D by the government as a whole and by various agencies, particularly in chemistry and chemical engineering...............38

3 Industry

How much industry, especially the chemical industry, spends. Where industrial chemists work and how well they are paid.............................47

4 Universities & Colleges

Where academic institutions get funds and how they spend them. Who spends the most for chemistry and for chemical engineering.........52

5 International

How R&D efforts in the U.S. compare with those in other countries, particularly Japan and the countries of Western Europe............................60

Research Triangle Institute photo

OHM Corp. photo

Steadiness is also apparent in the share of the gross national product (GNP) claimed by R&D in recent years. After growing dramatically from a low of 2.1% in 1978 to just over 2.8% in 1985, this percentage has hovered at about 2.8% or 2.9% for the past five years. Nondefense R&D leveled off sooner; it's held steady since 1982 at 1.9% of the value of all goods and services produced in the U.S.

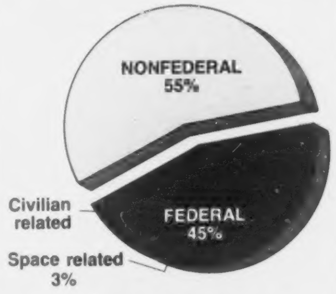
This measure is particularly useful in comparing the R&D efforts of different countries, since it factors in the relative size of the economies of various nations. In absolute terms, of course, the U.S. R&D effort dwarfs that of any other noncommunist country. (Comparisons with communist countries, with their very different economic structure, are not very meaningful.) In fact, in 1987—the most recent year for which most comparative data are available—U.S. R&D spending was more than the combined R&D expenditures of any 10 other countries for which data are available from the National Science Foundation. It was 2.8 times that of Japan, the next largest R&D spender.

But such comparisons are less useful than looking at R&D as a fraction of GNP for various countries. By this standard, the U.S. 1987 level of 2.9% matches that of Japan and marginally trails both Sweden and Israel, which each spent 3.0% of their GNP on R&D in the most recent year for which such data are available for each country. West Germany, at 2.8% of GNP, is also among the big spenders by this measure. The U.K., France, Switzerland, and the Netherlands spend between 2.0 and 2.5% of their GNP on R&D, and many other high-technology-based economies—such as Canada, Italy, Belgium, South Korea, and Taiwan—spend between 1.0 and 1.9%. Third World countries, not surprisingly, generally spend considerably less.

A look at the U.S.'s chief competitors in high-technology areas, those that benefit the most from R&D, shows that Japan and West Germany, like the U.S., steadily increased their R&D as a portion of their GNP throughout the early 1980s. Unlike the U.S., this percentage was still climbing for both of these countries in 1987, the last year for which figures are available. In 1987, all three countries spent either 2.8% or 2.9% of their GNP on R&D. There is a considerable difference in the nondefense R&D spending of the three countries, however; both Japan and West Germany spend a much smaller fraction of their R&D on defense. Although U.S. nondefense R&D plateaued at 1.9% of GNP in 1982, that of Japan and West Germany continued to climb through 1985, reaching levels of 2.6% for West Germany and 2.8% for Japan in that year.

Another measure of the effect of R&D on the technology-intensive part of the economy, and one that focuses more directly on chemical technology, is of U.S. patent activity in recent years. Although most U.S. chemical patents are still issued to U.S. corporations, individuals, or the federal government, they accounted for only 52% of the total last year. A decade earlier, U.S. recipients claimed 60% of these patents. Over the past decade, West Germany has received a steady 10 to 11% of the total, but Japan has increased its share every year—from 11% in 1979 to 20% in 1988. The U.K., France, Switzerland, and Canada round out the nations that claimed more than 1% of U.S. chemical patents last year. In fact, of the 20 corporations receiving the greatest number of chemical patents last year, only 15 are based in the U.S. and the other five have headquarters in West Germany, Japan, and the U.K.

Federal funds account for almost half of all U.S. R&D

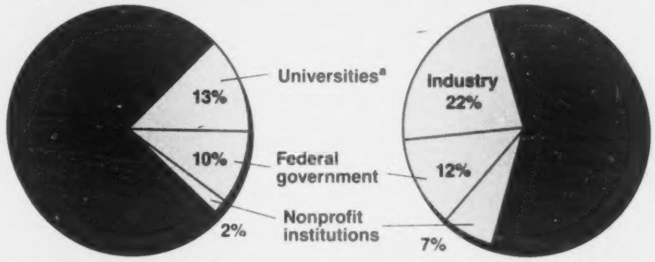


Estimated 1989 total R&D spending = $145 billion

Source: C&EN estimates based on data from the National Science Foundation

The 6% increase for total R&D spending in the U.S. this year and last provides a healthy climate for R&D in chemistry and chemical engineering. No recent data are available for measuring the total number of dollars going into chemical R&D of all types. However, a few clues provide some insight.

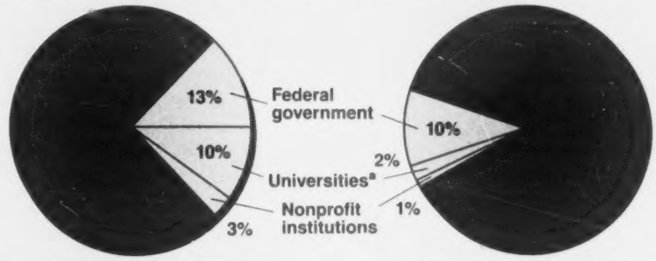
Industry performs three quarters of all R&D, even though universities do most basic research...



Estimated 1989 total R&D spending = $145 billion

Estimated 1989 basic research spending = $20 billion

...because it accounts for nearly three quarters of applied research and all but 13% of development



Estimated 1989 applied research spending = $34 billion

Estimated 1989 development spending = $91 billion

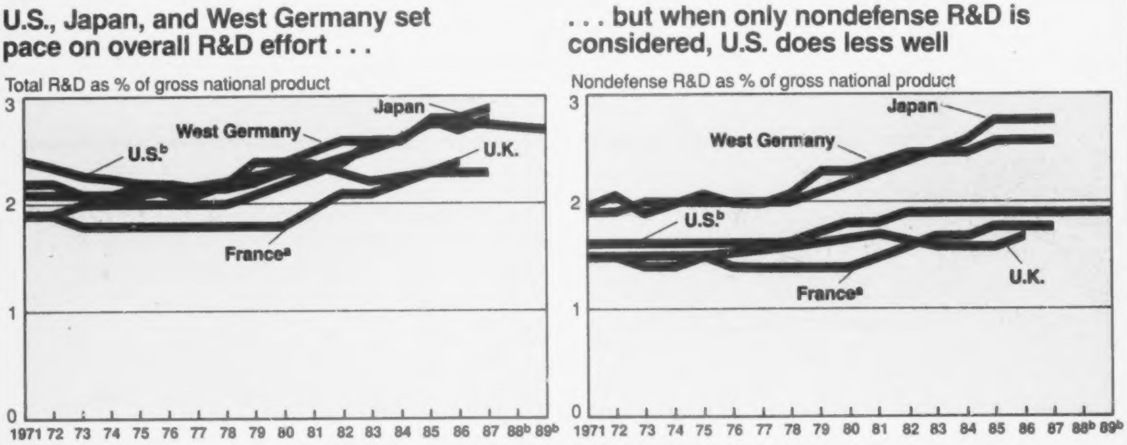
[a] Includes associated federally funded R&D centers.

Source: C&EN estimates based on data from the National Science Foundation

NSF estimates that the federal government was the source for $677 million in funds for chemical research in the past fiscal year (a figure that excludes money spent for development work), essentially unchanged from the amount government agencies provided in the year before. Three quarters of these funds came from just four agencies: the departments of Energy, of Defense, and of Health & Human Services, and from NSF. Federal agencies also are estimated by NSF to have provided $245 million for chemical engineering research, a 13% boost from fiscal 1987 to a level about the same as in 1986 and 1985. All told, though, government support of chemical and chemical engineering research is relatively modest, accounting for a mere 5% of federal outlays for all scientific research. The life sciences, physics, and environmental sciences are recipients of far heftier sums of money.

Even fewer chemical R&D dollars are funded by the universities. In 1987 (the most recent year for which figures are available), chemical R&D spending at universities totaled $508 million; for chemical engineering the total was $140 million. But 72% of the chemical funds and half of those for chemical engineering were provided by the federal government, leaving just about $200 million that was provided by the universities themselves, by industry, or by other sources. The amount of nonfederally funded chemical and chemical engineering R&D has nearly tripled since 1980. Even so, it still amounts to relatively few dollars.

The results of chemical research have proven commercial value. Consequently, it is not surprising that industry is by far the most generous supporter of chemical and chemical engineering R&D, especially the chemical industry itself. Last year, C&EN estimates, the amount of money plowed by all U.S. industry into R&D increased 6%—to top $100



U.S., Japan, and West Germany set pace on overall R&D effort . . .

. . . but when only nondefense R&D is considered, U.S. does less well

a French data are based on gross domestic product, consequently percentages may be slightly overstated. b C&EN estimates. **Source:** National Science Foundation

billion for the first time ever. Outlays by producers of chemicals and allied products, meanwhile, rose 11% to $11 billion, thanks largely to a 17% boost by drugmakers, who are easily the biggest R&D spenders in the overall chemical industry.

Data from earlier years indicate that about 70% of the R&D done by the chemicals and allied products industry, as well as 3% of that performed by all other industries, is focused on various aspects of chemical science or technology. This suggests, therefore, that last year industry devoted something on the order of $10.4 billion to work in chemical fields. Relatively little of this money comes from federal agencies, probably less than $400 million.

Couple that $10 billion in expenditures by industry with the roughly $1 billion divvied up from nonindustrial sources, and the total U.S. funding for chemical and chemical engineering R&D came to roughly $11 billion in 1988—about 8% of the money that went into all types of R&D.

There are a few changes this year in the tables that make up the main body of Facts & Figures of R&D. Added is a new international section, comparing the U.S. R&D effort with that of some 20 other nations, but particularly with that of Japan, West Germany, the U.K., and France. Presentation of estimated figures in the tables in many sections has been changed. Data for this report come from several sources, but the great bulk of the information is compiled by NSF's division of science resources studies. NSF collects the most comprehensive information on U.S. R&D and is the only source of many of the detailed breakdowns showing where that effort is focused. But compiling data with such completeness and detail is time-consuming, and NSF usually needs about a year and a half to publish its information. To make its data more current, NSF in many cases estimates recent levels of spending, estimates that are constantly being revised. And C&EN sometimes additionally revises these estimates, based on more current information from NSF as well as from other sources.

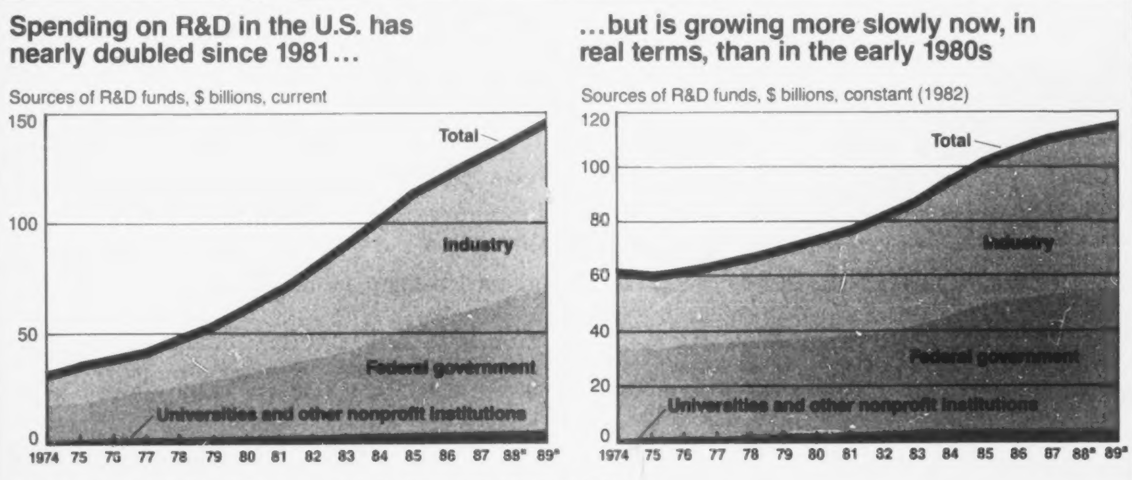
Every figure in this report for 1989, of course, is an estimate, and many of those for 1988 are as well. Although C&EN always indicates which data in the tables are estimates, this year the columns of tables that contain estimated data also are shaded. In addition, data for annual changes included in many tables are now calculated for the most recent year for which firm historical data are available—generally 1987—rather than for years for which only estimates are available. (Experience has suggested that estimates for R&D spending can turn out to be well off the mark.) □

For further information

Information for this Special Report is collected from many sources, but one important one is the National Science Foundation's division of science resources studies. This division publishes detailed statistical studies of each of the areas covered in this report. The studies contain a great deal of information not included here. Further overview information on the U.S. R&D effort is available in "National Patterns of R&D Resources: 1989," NSF publication No. 89-308. More information on funding from the federal government is in "Federal Funds for Research and Development, Fiscal Years 1987, 1988, and 1989," NSF publication No. 89-304. Industry data are provided in "Research & Development in Industry, 1987." Detailed information on universities and colleges is in "Academic Science/Engineering: R&D Funds, Fiscal Year 1987," and international comparisons may be found in "International Science & Technology Data Update: 1988," NSF publication No. 89-307. These studies are available in paper form or in some cases on diskettes from the National Science Foundation, Division of Science Resources Studies, Office of the Director, 1800 G St., N.W., Washington, D.C. 20402, telephone (202) 634-4622.

1 R&D Overview

Steady Growth Brings R&D to $145 Billion



Note: Industry data for 1982–89 are C&EN estimates. a Estimated. **Source:** National Science Foundation

SOURCES OF R&D FUNDS: Industry provides half, universities' small share is growing

														Annual change	
$ Billions, current	**1989[a]**	**1988[a]**	**1987**	**1986**	**1985**	**1984**	**1983**	**1982**	**1981**	**1980**	**1979**	**1978**	**1977**	**1986–87**	**1977–87**
Industry	$ 74.9	$ 70.7	$ 66.3[a]	$ 63.1[a]	$ 59.6[a]	$ 53.6[a]	$45.8[a]	$41.1[a]	$35.9	$30.9	$26.1	$22.5	$19.6	5%	13%
Federal government	64.8	61.9	58.5[a]	54.5[a]	51.8[a]	45.5[a]	40.7	36.5	33.4	29.5	26.8	23.9	21.6	5	10
Universities and colleges	3.8	3.5	3.1	2.8	2.4	2.1	1.9	1.7	1.6	1.3	1.2	1.0	0.9	13	13
Other nonprofit institutions	1.8	1.7	1.6	1.4	1.4	1.2	1.1	1.0	1.0	0.9	0.8	0.8	0.7	14	9
TOTAL	**$145.3**	**$137.8**	**$129.6**	**$121.8**	**$115.1**	**$102.4**	**$89.6**	**$80.4**	**$71.9**	**$62.6**	**$54.9**	**$48.1**	**$42.8**	**6%**	**12%**
ANNUAL CHANGE	**6%**	**6%**	**6%**	**6%**	**12%**	**14%**	**11%**	**12%**	**15%**	**14%**	**14%**	**12%**	**10%**		

$ Billions, constant 1982															
Industry	$ 59.3	$ 58.1	$ 56.3	$ 55.4	$ 53.7	$ 49.8	$44.1	$41.1	$38.2	$36.1	$33.2	$31.1	$29.2	2%	7%
Federal government	51.3	50.5	49.7	47.8	46.7	42.2	39.2	36.5	35.5	34.4	34.1	33.1	32.2	4	4
Universities and colleges	3.0	2.9	2.7	2.4	2.1	2.0	1.9	1.7	1.7	1.5	1.5	1.4	1.3	9	7
Other nonprofit institutions	1.4	1.4	1.4	1.3	1.2	1.1	1.1	1.0	1.0	1.1	1.1	1.1	1.0	10	3
TOTAL	**$115.0**	**$112.9**	**$110.1**	**$106.9**	**$103.8**	**$95.1**	**$86.2**	**$80.4**	**$76.5**	**$73.0**	**$69.9**	**$66.7**	**$63.7**	**3%**	**6%**
ANNUAL CHANGE	**2%**	**3%**	**3%**	**3%**	**9%**	**10%**	**7%**	**5%**	**5%**	**5%**	**5%**	**5%**	**2%**		

Note: Constant-dollar values are calculated by C&EN based on NSF data. a C&EN estimates. **Source:** National Science Foundation

PERFORMERS OF R&D: Industrial R&D, three fourths of total, now tops $100 billion

$ Billions, current	1989a	1988a	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	Annual change 1986–87	Annual change 1977–87
Industry	$108.2	$102.3	$ 96.3a	$ 89.9a	$ 85.6a	$ 76.1a	$65.7a	$59.0a	$51.8	$44.5	$38.2	$33.3	$29.8	7%	12%
Federal government	14.8	14.5	13.4	13.5	12.9	11.6	10.6	9.1	8.4	7.6	7.4	6.8	6.0	−1	8
Universities and colleges	13.9	13.0	12.1	10.9	9.7	8.6	7.9	7.3	6.8	6.1	5.4	4.6	4.1	11	11
University-associated FFRDCsb	4.7	4.4	4.2	3.9	3.5	3.1	2.7	2.5	2.5	2.2	1.9	1.7	1.4	8	12
Other nonprofit institutions	3.7	3.6	3.6	3.5	3.3	3.0	2.7	2.4	2.3	2.2	2.0	1.7	1.5	2	9
TOTAL	**$145.3**	**$137.8**	**$129.6**	**$121.8**	**$115.1**	**$102.4**	**$89.6**	**$80.4**	**$71.9**	**$62.6**	**$54.9**	**$48.1**	**$42.8**	**6%**	**12%**

$ Billions, constant 1982	1989a	1988a	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	Annual change 1986–87	Annual change 1977–87
Industry	$ 85.7	$ 84.1	$ 81.8	$ 78.9	$ 77.2	$ 70.7	$63.2	$59.0	$55.1	$51.9	$48.7	$46.1	$44.3	4%	6%
Federal government	11.7	11.9	11.4	11.9	11.7	10.7	10.2	9.1	9.0	8.9	9.4	9.4	9.0	−4	2
Universities and colleges	11.0	10.7	10.3	9.6	8.7	8.0	7.6	7.3	7.3	7.1	6.8	6.4	6.1	7	5
University-associated FFRDCsb	3.7	3.6	3.6	3.4	3.2	2.9	2.6	2.5	2.6	2.6	2.5	2.4	2.1	4	5
Other nonprofit institutions	2.9	3.0	3.0	3.1	3.0	2.8	2.6	2.4	2.4	2.5	2.5	2.3	2.2	−1	3
TOTAL	**$115.0**	**$113.2**	**$110.1**	**$106.9**	**$103.8**	**$ 95.1**	**$86.2**	**$80.4**	**$76.5**	**$73.0**	**$69.9**	**$66.7**	**$63.7**	**3%**	**6%**

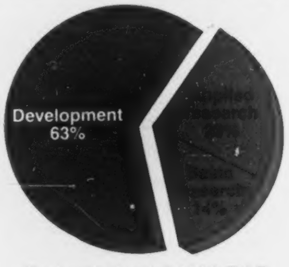
Note: Constant-dollar values are calculated by C&EN based on NSF data. a C&EN estimates. b Federally funded R&D centers. **Source:** National Science Foundation

U.S. CHEMICAL PATENTS: Nearly half go to foreign corporations, individuals, or governments

Number of patents issued	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979a	Total 1979–88
U.S. origin	**11,229**	**11,384**	**10,500**	**11,531**	**11,497**	**10,554**	**10,608**	**12,690**	**11,239**	**9,285**	**110,517**
to U.S. corporations	9,799	9,885	9,189	10,169	10,112	9,142	9,167	10,974	9,674	8,078	96,189
to U.S. government	265	325	290	322	376	331	311	364	360	272	3,216
to individuals in the U.S.	1,012	1,046	927	989	933	985	1,029	1,278	1,127	873	10,199
to foreign-owned corporations in the U.S.	153	128	94	51	76	96	101	74	78	62	913
Foreign origin	**10,529**	**10,248**	**9,110**	**9,697**	**8,996**	**8,068**	**8,016**	**9,618**	**8,361**	**6,440**	**89,083**
to U.S.-owned corporations abroad	866	849	758	884	834	702	731	896	818	623	7,961
to foreign corporations	8,892	8,644	7,674	8,086	7,439	6,711	6,514	7,855	6,768	5,265	73,848
to foreign governments	194	200	148	162	167	133	166	100	96	78	1,444
to foreign individuals	577	555	530	565	556	522	605	767	679	474	5,830
TOTAL	**21,758**	**21,632**	**19,610**	**21,228**	**20,493**	**18,622**	**18,624**	**22,308**	**19,600**	**15,725**	**199,600**
% Foreign	**48.4%**	**47.4%**	**46.5%**	**45.7%**	**43.9%**	**43.3%**	**43.0%**	**43.1%**	**42.7%**	**41.0%**	**44.6%**

Note: Includes patents issued in those technology subclasses that the U.S. Patent & Trademark Office classifies as chemical. a Patent figures were low in 1979 because the U.S. Patent & Trademark Office was short of funds to print patents. **Source:** U.S. Patent & Trademark Office

Development claims nearly two thirds of all R&D funds



Estimated total 1989 R&D spending = $145 billion

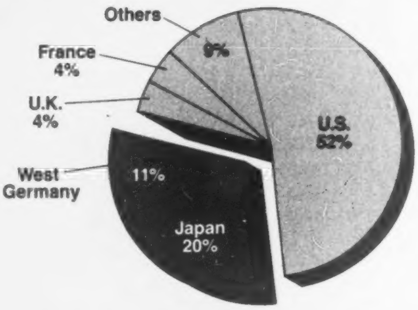
Source: C&EN estimates

RECIPIENTS OF U.S. CHEMICAL PATENTS: Japan's share has nearly doubled in past decade

% of patents	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	Total 1979–88
U.S. origin	**52%**	**53%**	**54%**	**54%**	**56%**	**57%**	**57%**	**57%**	**57%**	**59%**	**55%**
Foreign origina	**48**	**47**	**46**	**46**	**44**	**43**	**43**	**43**	**43**	**41**	**45**
Japan	20	19	19	18	16	15	14	13	12	11	16
West Germany	11	10	10	10	10	11	11	11	11	11	11
U.K.	4	4	4	4	4	4	4	4	5	4	4
France	4	4	3	3	3	3	4	4	4	3	4
Switzerland	2	2	2	2	2	2	2	2	3	3	2
Canada	2	1	1	2	1	1	1	1	1	1	1
Italy	1	1	1	1	1	1	1	1	2	1	1
Netherlands	1	1	1	1	1	1	1	1	1	1	1
Sweden	1	1	1	1	1	1	1	1	1	1	1
Belgium	1	1	1	1	1	1	1	1	1	1	1
U.S.S.R.	—	—	—	—	—	—	—	1	1	1	—

Note: Includes patents issued in those technology subclasses that the U.S. Patent & Trademark Office classifies as chemical. a Data for individual countries may not equal this number because of rounding. **Source:** U.S. Patent & Trademark Office

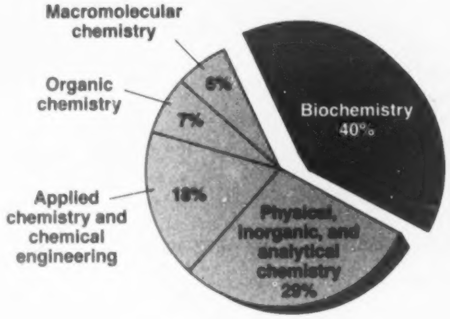
Japan and West Germany claim almost a third of U.S. chemical patents



1988 total U.S. chemical patents issued = 21,758

Source: U.S. Patent & Trademark Office

Biochemistry accounts for 40% of all papers in chemistry fields



1988 total[a] = 389,685

[a] Number of abstracts of papers published in *Chemical Abstracts*.
Source: Chemical Abstracts Service

PATENT ACTIVITY OF U.S. COMPANIES: Dow and Du Pont lead list for chemical firms

Number of patents issued	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979[a]	Total 1979–88
CHEMICAL COMPANIES											
Dow Chemical	421	469	371	335	328	246	276	260	249	217	**3,172**
Du Pont[b]	375	449	371	395	416	387	331	430	349	287	**3,790**
Ciba-Geigy	279	286	244	305	290	244	281	345	309	248	**2,831**
Union Carbide	141	159	208	242	231	182	202	262	211	197	**2,035**
PPG Industries	118	118	124	128	137	137	177	189	166	118	**1,412**
American Cyanamid	101	107	92	115	111	128	129	188	205	143	**1,319**
Dow Corning	82	58	68	55	52	37	35	50	31	26	**494**
Monsanto	76	91	110	100	138	136	131	211	205	144	**1,342**
Stauffer Chemical	69	94	75	104	95	81	87	94	93	80	**872**
Olin	59	58	81	117	112	85	80	80	106	82	**860**
Ethyl	51	48	77	105	76	44	31	43	51	25	**551**
W. R. Grace	46	43	42	45	57	52	49	68	72	56	**530**
Hercules	32	50	43	41	39	37	30	52	23	24	**371**
International Flavors & Fragrances	24	38	76	104	95	87	87	96	76	60	**743**
GAF	23	15	12	23	19	21	32	47	48	54	**294**
Rohm & Haas	18	22	33	31	37	55	49	77	74	77	**473**
TOTAL[c]	**1915**	**2105**	**2027**	**2245**	**2233**	**1959**	**2007**	**2492**	**2268**	**1838**	**21,089**
ANNUAL CHANGE	**−9%**	**4%**	**−10%**	**1%**	**14%**	**−2%**	**−19%**	**10%**	**23%**	**−49%**	
DRUG COMPANIES											
Merck	125	123	103	105	135	114	135	160	156	127	**1,283**
Warner-Lambert	113	118	101	73	49	34	25	37	36	36	**622**
Squibb	74	75	70	74	53	37	56	62	85	98	**684**
American Home Products	69	46	38	49	32	24	43	52	52	39	**444**
Eli Lilly	68	85	82	107	80	74	104	112	85	84	**881**
Pfizer	63	67	72	72	89	61	72	92	75	65	**728**
Hoffmann-LaRoche	59	86	84	74	78	90	118	124	144	126	**983**
SmithKline Beckman	56	54	27	43	68	59	66	59	82	71	**585**
Upjohn	15	26	66	66	107	73	122	337	170	196	**1,178**
TOTAL[c]	**642**	**680**	**643**	**663**	**691**	**566**	**741**	**1035**	**885**	**842**	**7,388**
ANNUAL CHANGE	**−6%**	**6%**	**−3%**	**−4%**	**22%**	**−24%**	**−28%**	**17%**	**5%**	**−33%**	

Note: Includes U.S. chemical and drug companies and U.S. subsidiaries of foreign companies that have received more than 1000 U.S. patents since 1962. a Patent figures were low in 1979 because the U.S. Patent & Trademark Office was short of funds to print patents. b Includes patents issued to Conoco, acquired in 1981, for all years. c These totals include patents issued to companies in this table only. **Source:** U.S. Patent & Trademark Office

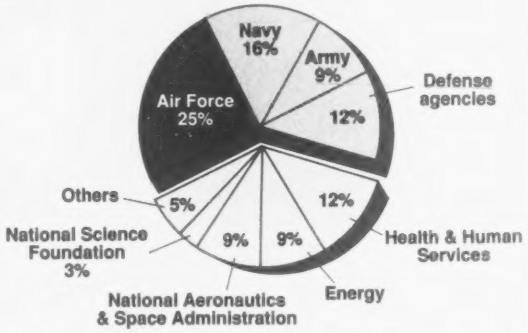
ABSTRACTS OF PAPERS IN *CHEMICAL ABSTRACTS:* Biochemistry's dominant share down slightly

	1988	1987	1986	1985	1984	1983	1982	1978	Change 1977-87
BIOCHEMISTRY	39.7%	40.5%	40.4%	40.5%	40.5%	38.3%	39.5%	38.3%	1.4%
% of all biochemistry abstracts									
Mammalian hormones[a]	12.7	12.2	12.5	12.3	12.4	12.9	12.2	12.3	0.4
Pharmacology	12.0	12.6	12.2	12.3	11.6	11.8	12.0	5.9	6.1
Mammalian biochemistry[a]	10.8	11.1	10.8	11.1	11.3	11.1	11.6	17.2	−6.4
Toxicology	7.9	8.3	7.8	7.9	8.0	8.5	8.1	7.5	0.4
Biochemical genetics[b]	7.6	6.7	6.1	5.2	4.2	3.8	3.3	—	—
Enzymes	6.1	5.4	5.6	5.6	5.8	6.1	5.9	5.7	0.4
Immunochemistry	5.8	5.8	6.1	5.3	4.8	4.2	4.4	3.6	2.2
General biochemistry	5.3	4.6	4.7	4.9	5.3	5.8	6.0	6.5	−1.2
Biochemical methods	5.1	4.8	5.0	4.9	4.9	4.9	4.6	4.6	0.5
Plant biochemistry[a]	5.0	5.3	5.2	5.5	6.2	5.9	6.2	5.4	−0.4
Microbial biochemistry[a]	4.8	5.1	5.7	5.7	5.2	5.1	5.3	5.1	−0.3
Others	16.9	18.1	18.3	19.3	20.3	19.9	20.4	26.2	−9.3
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	—
PHYSICAL, INORGANIC, AND ANALYTICAL CHEMISTRY	28.8%	29.0%	29.8%	29.8%	28.8%	29.6%	28.5%	27.4%	1.4%
% of all physical, inorganic, and analytical chemistry abstracts									
Spectra	20.0	20.4	20.0	18.4	18.0	17.6	17.2	17.0	3.0
Nuclear chemistry	17.8	19.5	19.9	21.8	22.2	22.5	22.6	20.7	−2.9
Electric phenomena	12.5	10.9	10.8	10.8	10.8	10.0	10.5	10.9	1.6
General physical chemistry	7.2	7.9	7.0	6.9	6.9	7.3	7.3	6.6	0.6
Crystallography and liquid crystals	7.0	7.1	7.0	7.5	7.8	8.3	8.7	9.2	−2.2
Analytical chemistry	5.7	5.9	6.8	6.1	6.3	6.2	5.4	7.2	−1.5
Others	29.8	28.3	28.5	28.5	28.0	28.1	28.3	28.4	1.4
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	—
APPLIED CHEMISTRY AND CHEMICAL ENGINEERING	18.6%	18.0%	18.2%	18.4%	17.6%	19.4%	19.5%	20.8%	−2.2%
% of all applied chemistry and chemical engineering abstracts									
Metals and alloys	21.7	20.6	20.8	20.0	18.9	19.1	22.2	24.0	−2.3
Water, wastes, and pollution	20.4	20.4	21.9	20.2	21.0	19.6	21.7	20.8	−0.4
Mineralogical and geological chemistry	11.8	11.2	12.0	12.5	14.6	14.1	13.6	16.8	−5.0
Fossil fuels, derivatives, and related products	8.8	9.6	9.0	10.1	10.1	10.3	9.4	8.2	0.6
Unit operations and processes	8.0	9.0	7.1	7.5	7.0	7.5	6.9	6.4	1.6
Pharmaceuticals and pharmaceutical analysis	7.6	7.8	8.2	8.0	7.0	6.5	6.3	5.6	2.0
Ceramics	6.7	6.3	5.8	5.6	5.1	5.4	4.5	4.1	2.6
Others	15.0	15.1	15.2	16.1	16.3	17.5	15.4	14.1	0.9
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	—
ORGANIC CHEMISTRY	7.3%	6.9%	5.9%	6.4%	7.6%	7.3%	7.2%	8.0%	−0.7%
% of all organic chemistry abstracts									
Physical organic chemistry	23.0	23.9	27.3	30.6	32.0	30.5	31.5	36.8	−13.8
Organometallic and organometalloidal compounds	18.8	16.1	18.3	16.2	17.1	16.3	14.8	17.5	1.3
Heterocyclic compounds[a]	15.7	19.9	15.0	16.1	15.6	16.2	15.6	8.9	6.8
Carbohydrates	8.1	5.6	7.8	5.7	5.7	5.8	5.8	5.2	2.9
Aromatic compounds[a]	7.2	7.7	7.3	6.3	6.3	7.1	7.2	8.6	−1.4
Biomolecules and their synthetic analogs[b]	6.1	5.8	5.0	4.9	4.4	4.5	3.7	—	—
Amino acids, peptides, and proteins[a]	5.8	4.3	3.9	4.6	4.8	4.5	4.4	4.0	1.8
Aliphatic compounds[a]	4.1	4.9	4.4	4.2	3.6	4.3	5.2	6.9	−2.8
Others	11.2	11.8	11.0	11.4	10.5	10.8	11.8	12.1	−0.9
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	—
MACROMOLECULAR CHEMISTRY	5.6%	5.6%	5.7%	4.9%	5.5%	5.4%	5.3%	5.5%	0.1%
% of all macromolecular chemistry abstracts									
Synthetic high polymers	34.8	35.2	34.1	34.1	34.0	34.4	34.7	25.6	9.2
Plastics manufacture and uses	23.7	23.6	23.8	25.3	24.2	24.4	21.9	28.1	−4.4
Cellulose, lignin, paper, and other wood products	9.6	8.8	9.8	9.1	9.6	9.1	9.7	10.6	−1.0
Textiles	7.3	8.1	8.8	8.2	7.3	7.9	8.9	12.1	−4.8
Synthetic elastomers and natural rubber	6.7	7.2	6.7	6.8	7.3	7.5	7.8	7.5	−0.8
Coatings, inks, and related products	5.7	5.8	7.2	7.2	7.8	6.6	7.6	8.0	−2.3
Others	12.2	11.3	9.6	9.3	9.8	10.1	9.4	8.1	4.1
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	—

How to read this table: Using biochemistry as an example, in 1988 39.7% of all the papers abstracted by Chemical Abstracts Service are in the various subdisciplines of biochemistry; 12.7% of all abstracts in biochemistry, in turn, are in the subdiscipline of pharmacology, and so on. a Definition of section changed in 1982. b New section in 1982. **Source:** Chemical Abstracts Service

Defense's Mammoth Share Is Leveling Off

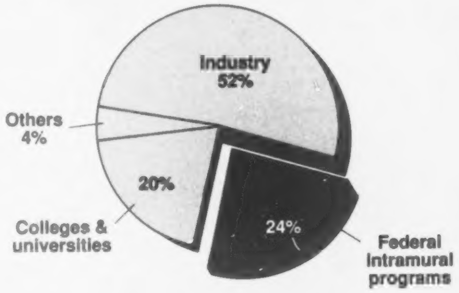
A fourth of federal R&D outlays comes from Air Force . . .



Estimated fiscal 1989 total federal R&D obligations = $60.3 billion

Source: National Science Foundation

. . . and about a fourth of the R&D is performed at federal facilities



Estimated fiscal 1989 total federal R&D obligations = $60.3 billion

FEDERAL OBLIGATIONS FOR R&D: Growth in health, space, and at NSF outpace that at DOD

$ Millions	1989ª	1988ª	1987	1986	1985	1984	1983	1982	Annual change 1986–87	Annual change 1982–87
Defense	$37,505	$36,543	$35,232	$32,938	$29,792	$25,373	$22,993	$20,623	7%	11%
Air Force	15,279	15,520	15,348	13,594	13,261	12,092	10,813	9,358	13	10
Navy	9,432	9,631	9,508	9,650	9,127	7,606	6,068	5,845	−1	10
Army	5,250	4,921	5,020	4,809	4,571	4,226	3,998	3,761	4	6
Defense agencies	7,246	6,244	5,220	4,767	2,782	1,392	2,052	1,618	9	26
Health & Human Services	7,043	7,112	6,609	5,658	5,451	4,831	4,353	3,941	17	11
National Institutes of Health	6,233	6,321	5,853	5,005	4,828	4,257	3,789	3,433	17	11
Alcohol, Drug Abuse & Mental Health Administration	523	498	476	396	378	337	302	248	20	14
National Aeronautics & Space Administration	5,416	4,779	3,787	3,420	3,327	2,822	2,662	3,078	11	4
Energy	5,182	5,101	4,757	4,688	4,996	4,674	4,537	4,708	1	0
National Science Foundation	1,827	1,523	1,471	1,353	1,346	1,203	1,062	975	9	9
Agriculture	987	1,020	948	929	943	866	848	797	2	4
Agricultural Research Service	529	513	479	463	470	451	443	405	3	3
Cooperative State Research Service	256	296	271	269	284	236	232	219	1	4
Forest Service	129	136	127	113	113	108	108	112	12	2
Interior	376	420	404	385	392	411	383	381	5	1
Geological Survey^{b}	222	236	227	219	215	209	157	153	4	8
Environmental Protection Agency	374	350	348	317	320	261	241	335	10	1
Commerce	308	411	402	399	399	358	335	336	1	4
National Oceanic & Atmospheric Administration	176	282	286	275	270	244	222	222	4	5
National Institute of Standards & Technology	118	111	99	101	101	96	95	89	−2	2
Others	1,306	1,253	1,298	1,325	1,367	1,427	1,300	1,258	−2	1
TOTAL	$60,323	$58,512	$55,255	$51,412	$48,332	$42,225	$38,712	$36,433	7%	9%
ANNUAL CHANGE	3%	6%	7%	6%	14%	9%	6%	6%		

Note: Fiscal years. **a** Estimated. **b** Includes Office of Water Research & Technology. **Source:** National Science Foundation

PERFORMERS OF FEDERALLY FUNDED R&D: Universities' share of total is growing

Federal obligations, $ millions	1989[a]	1988[a]	1987	1986	1985	1984	1983	1982	Annual change 1986–87	Annual change 1982–87
Industry	$31,107	$30,121	$28,612	$26,206	$23,760	$20,382	$18,649	$18,699	9%	9%
FFRDCs[b] administered by industry	1,923	1,888	1,860	1,697	1,791	1,608	1,501	1,506	10	4
Federal Intramural Programs	14,745	14,514	13,413	13,533	12,998	11,572	10,582	9,141	−1	8
Universities and colleges	11,805	11,142	10,563	9,019	8,892	7,890	7,232	6,582	17	10
FFRDCs[b] administered by universities	3,638	3,371	3,210	2,440	2,535	2,325	2,266	1,977	32	10
Nonprofit institutions	2,234	2,315	2,221	2,228	2,388	2,094	1,823	1,612	0	7
FFRDCs[b] administered by nonprofit institutions	528	514	511	553	689	597	581	521	−8	0
Foreign	290	272	298	296	245	176	240	214	0	7
State and local governments	142	148	148	128	129	131	186	184	15	−4
TOTAL	$60,323	$58,512	$55,255	$51,412	$48,360	$42,225	$38,712	$36,433	7%	9%

Note: Fiscal years. a Estimated. b Federally funded R&D centers. **Source:** National Science Foundation

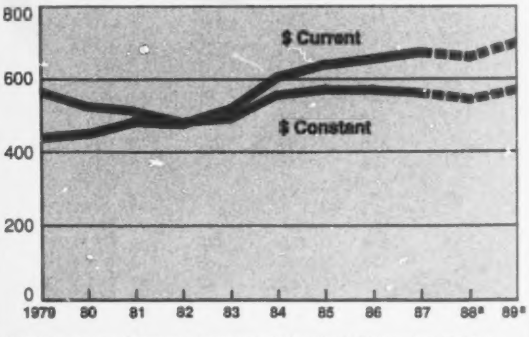
FEDERAL OBLIGATIONS FOR SCIENTIFIC DISCIPLINES: Small gain for chemistry

$ Millions for research only	1989[a]	1988[a]	1987	1986	1985	1984	1983	1982	Annual change 1986–87	Annual change 1982–87
Life sciences	$ 7,954	$ 7,809	$ 7,344	$ 6,464	$ 6,366	$ 5,636	$ 5,178	$ 4,746	14%	9%
Engineering	4,253	4,082	3,906	3,739	3,629	3,624	3,517	3,387	4	3
Chemical	187	245	216	246	254	145	145	95	−12	18
Metallurgy and materials	415	461	362	445	439	341	333	309	−19	3
National engineering centers	624	639	669	632	664	858	828	788[a]	6	−3
Physical sciences	3,707	3,387	3,253	3,069	3,044	2,969	2,891	2,500	6	5
Chemistry	705	677	680	662	645	606	520	481	3	7
Physics	2,112	1,940	1,854	1,806	1,820	1,836	1,855	1,611	3	3
Environmental sciences	1,691	1,631	1,512	1,482	1,404	1,276	1,251	1,148	2	6
Mathematical and computer sciences	787	682	641	615	578	440	419	350	4	13
Other sciences	1,321	1,273	1,288	1,133	1,110	1,034	997	891	14	8
TOTAL	$19,712	$18,864	$17,943	$16,502	$16,130	$14,979	$14,254	$13,022	9%	7%
ANNUAL CHANGE	4%	5%	9%	2%	8%	5%	9%	7%		

Note: Fiscal years. a Estimated. **Source:** National Science Foundation

Federal support for chemical research changed little in real terms since 1985

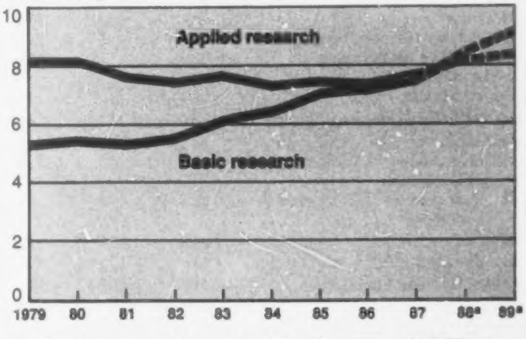
Federal obligations for research, $ millions



Note: Fiscal years. Constant-dollar values calculated by C&EN based on NSF data. a Estimated. **Source:** National Science Foundation

Funding for basic research has overtaken that for applied research

Federal obligations for research, $ billions, constant (1982)



Note: Fiscal years. Constant-dollar values calculated by C&EN based on NSF data. a Estimated. **Source:** National Science Foundation

2 R&D Federal Government

FEDERAL OBLIGATIONS FOR BASIC RESEARCH: Growth slows since early 1980s

$ Millions	1989[a]	1988[a]	1987	1986	1985	1984	1983	1982	Annual change 1986–87	Annual change 1982–87
Health & Human Services	$ 4,240	$4115	$3830	$3339	$3233	$2815	$2475	$2145	15%	12%
National Institutes of Health	3,964	3853	3577	3119	3018	2625	2313	2021	15	12
Alcohol, Drug Abuse & Mental Health Administration	255	241	232	203	197	171	145	117	14	15
National Science Foundation	1,708	1418	1371	1275	1262	1132	999	916	8	8
National Aeronautics & Space Administration	1,374	1229	1014	917	751	755	617	536	11	14
Energy	1,267	1194	1069	960	943	830	768	642	11	11
Defense	947	885	908	924	861	848	786	687	−2	6
Navy	357	342	354	337	343	316	305	280	5	5
Air Force	220	201	222	216	198	192	164	146	2	9
Army	176	166	217	248	241	222	208	188	−13	3
Defense agencies	194	176	115	122	79	118	108	73	−6	10
Agriculture	471	472	446	433	445	393	362	331	3	6
Agricultural Research Service	280	272	253	248	250	241	215	193	2	6
Cooperative State Research Service	132	139	133	132	142	100	99	91	1	8
Forest Service	49	52	49	42	44	41	39	39	17	5
Interior	122	135	135	133	138	126	103	77	1	12
Geological Survey[b]	87	89	85	83	81	79	65	53	2	10
Bureau of Mines	30	41	46	45	50	41	24	13[a]	2	29
Environmental Protection Agency	31	32	31	39	39	30	22	33	−21	−1
Commerce	27	28	26	27	23	21	19	17	−3	9
National Institute of Standards & Technology	26	27	25	26	22	20	18	17	−2	9
Others	114	117	116	107	124	119	109	99	8	3
TOTAL	$10,300	$9623	$8944	$8153	$7819	$7067	$6260	$5482	10%	10%
ANNUAL CHANGE	7%	8%	10%	4%	11%	13%	14%	14%		

Note: Fiscal years. a Estimated. Includes Office of Water Research & Technology. **Source:** National Science Foundation

FEDERAL OBLIGATIONS FOR APPLIED RESEARCH: Defense and health get nearly half

$ Millions	1989[a]	1988[a]	1987	1986	1985	1984	1983	1982	Annual change 1986–87	Annual change 1982–87
Defense	$2407	$2320	$2440	$2303	$2307	$2201	$2437	$2286	6%	1%
Army	595	547	693	579	583	487	485	452	20	9
Air Force	560	510	563	542	538	548	524	488	4	3
Navy	416	408	432	447	448	450	522	498	−3	−3
Defense agencies	836	854	751	735	738	717	906	828	2	−2
Health & Human Services	2273	2362	2195	1851	1796	1652	1545	1461	19	8
National Institutes of Health	1789	1883	1740	1469	1410	1286	1165	1104	18	10
Alcohol, Drug Abuse & Mental Health Administration	265	254	241	192	180	165	155	129	26	13
National Aeronautics & Space Administration	1700	1413	1256	1152	1033	955	928	871	9	8
Energy	959	1029	1029	1081	1198	1195	1193	1054	−5	0
Agriculture	485	517	473	464	466	442	456	436	2	2
Agricultural Research Service	222	215	201	188	192	184	203	186	7	2
Cooperative State Research Service	123	157	138	137	143	136	134	128	0	2
Forest Service	76	80	73	68	66	64	65	69	9	1
Environmental Protection Agency	261	243	246	179	176	142	152	211	37	3
Commerce	251	329	313	313	301	276	266	259	0	4
National Oceanic & Atmospheric Administration	159	240	234	237	224	198	189	189	−1	4
National Institute of Standards & Technology	82	74	64	63	65	64	63	57	1	2
Interior	232	260	247	235	231	254	255	275	5	−2
Geological Survey[b]	123	136	132	128	130	125	90	99	3	6
National Science Foundation	119	105	99	78	84	71	63	57	27	12
Others	727	663	700	693	720	725	699	651	1	1
TOTAL	$9412	$9241	$8999	$8349	$8312	$7911	$7993	$7541	8%	4%
ANNUAL CHANGE	2%	3%	8%	0%	5%	−1%	6%	5%		

Note: Fiscal years. a Estimated. b Includes Office of Water Research & Technology. **Source:** National Science Foundation

FEDERAL OBLIGATIONS FOR DEVELOPMENT: Defense's share holds steady at about 85%

$ Millions	1989[a]	1988[a]	1987	1986	1985	1984	1983	1982	Annual change 1986–87	Annual change 1982–87
Defense	$34,151	$33,338	$31,884	$29,711	$26,623	$22,324	$19,770	$17,700	7%	12%
Air Force	14,499	14,809	14,563	12,835	12,524	11,352	10,124	8,724	13	11
Navy	8,659	8,881	8,721	8,866	8,336	6,840	5,241	5,066	−2	11
Army	4,479	4,208	4,110	3,982	3,747	3,517	3,305	3,121	3	6
Defense agencies	6,216	5,213	4,354	3,911	1,965	557	1,039	717	11	43
Energy	2,956	2,878	2,659	2,648	2,825	2,649	2,576	3,012	0	−2
National Aeronautics & Space Administration	2,342	2,138	1,518	1,351	1,544	1,113	1,117	1,671	12	−2
Health & Human Services	531	636	584	468	423	365	332	335	25	12
National Institutes of Health	480	585	536	418	400	347	311	309	28	12
Environmental Protection Agency	63	76	71	100	106	89	66	92	−29	−5
Agriculture	31	31	29	32	32	31	30	31	−10	−1
Agricultural Research Service	26	26	24	27	28	27	26	26	−12	−1
Commerce	30	55	64	80	75	62	50	80	7	1
National Oceanic & Atmospheric Administration	17	42	52	37	45	47	33	34	39	9
National Institute of Standards & Technology	10	10	9	12	14	12	14	15	−20	−9
Interior	23	25	22	17	22	31	25	30	25	−6
Geological Survey[b]	12	11	10	7	4	5	2	1	38	83
National Science Foundation	0	0	0	0	0	0	0	2	—	—
Others	465	473	482	524	553	583	493	478	−8	0
TOTAL	$40,611	$39,648	$37,313	$34,910	$32,202	$27,246	$24,458	$23,410	7%	10%
ANNUAL CHANGE	2%	6%	7%	8%	18%	11%	4%	3%		

Note: Fiscal years. a Estimated. b Includes Office of Water Research & Technology. **Source:** National Science Foundation

ENGINEERING RESEARCH: NASA may edge out Pentagon as chief supporter of engineering researc

Federal obligations, $ millions	1989[a] All engineering	1989[a] Chemical engineering	1989[a] Metallurgy & materials	1988[a] All engineering	1988[a] Chemical engineering	1988[a] Metallurgy & materials	1987 All engineering	1987 Chemical engineering
National Aeronautics & Space Administration	$1585.7	$ 1.7	$ 23.0	$1340.5	$ 1.7	$ 21.1	$1170.5	$ 1.5
Defense	1580.4	45.3	247.2	1600.9	47.3	292.8	1629.7	46.9
Air Force	457.4	3.2	31.8	416.9	6.4	17.3	460.3	1.8
Navy	385.0	21.6	54.7	378.4	20.6	54.2	401.5	21.3
Army	366.9	20.2	24.2	358.8	20.1	21.1	442.4	23.8
Defense agencies	371.2	0.3	136.5	446.9	0.3	200.2	325.6	0
Energy	351.0	55.3	81.0	455.8	117.4	83.2	442.2	88.9
National Science Foundation	237.9	44.2	27.2	202.0	39.2	24.8	191.7	37.3
Transportation	72.5	0.4	0.2	59.5	0.7	0.8	48.1	1.0
Interior	69.2	4.6	23.5	89.6	5.2	27.1	87.8	5.0
Environmental Protection Agency	53.1	24.3	0.8	50.6	24.0	0.5	55.4	25.6
Commerce	50.3	5.3	11.5	47.7	2.9	11.1	41.3	2.4
Agriculture	29.0	6.2	0	33.2	6.3	0	33.9	6.9
Others	223.3	0	0	202.3	0	0	205.8	0.3
TOTAL	$4252.5	$187.3	$415.4	$4082.1	$244.7	$461.3	$3906.2	$215.8
ANNUAL CHANGE	4%	−23%	−10%	5%	13%	27%	4%	−12%

Note: Fiscal years. a Estimated. **Source:** National Science Foundation

FEDERAL OBLIGATIONS FOR CHEMICAL RESEARCH: Funding stalls for energy and defense

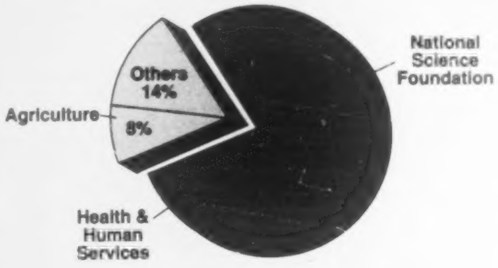
									Annual change	
$ Millions	1989[a]	1988[a]	1987	1986	1985	1984	1983	1982	1986–87	1982–87
Energy	$149.4	$157.4	$145.5	$145.9	$143.0	$140.4	$117.6	$105.4	0%	7%
Defense	130.2	116.2	144.9	163.4	156.4	139.8	121.8	118.1	−11	4
Army	56.8	52.3	72.2	81.4	78.2	66.3	59.3	61.4	−11	3
Air Force	43.0	39.2	43.3	42.0	39.5	36.7	31.2	27.2	3	10
Navy	27.1	24.2	28.4	39.1	38.3	36.6	31.1	29.4	−27	−1
Defense agencies	3.2	2.5	1.1	0.9	0.4	0.3	0.3	0.3	28	30
Health & Human Services	125.3	124.1	115.5	104.2	99.1	86.3	74.2	63.3	11	13
National Institutes of Health	117.8	116.6	108.1	99.5	95.1	84.1	72.2	62.6	9	12
Alcohol, Drug Abuse & Mental Health Administration	7.5	7.5	7.4	4.7	4.0	2.3	2.0	1.2[a]	56	44
National Science Foundation	137.8	116.7	115.3	112.6	115.6	109.9	92.4	86.1	2	6
Agriculture	59.0	60.2	65.0	58.6	58.0	69.0	63.8	58.5	11	2
Agricultural Research Service	40.9	39.7	46.4	40.0	36.1	51.6	49.5	44.7	16	1
Cooperative State Research Service	10.8	12.9	11.5	12.4	16.1	13.5	10.8	10.2	−7	2
Forest Service	7.3	7.6	7.1	6.2	5.7	3.9	3.6	3.8[a]	14	13
Environmental Protection Agency	34.5	33.3	34.6	20.1	17.5	15.9	14.8	18.8	72	13
Commerce	24.0	22.9	22.9	19.1	17.7	15.3	14.0	13.0	20	12
National Institute of Standards & Technology	18.2	16.7	16.5	16.4	15.4	14.1	12.7	11.5	1	7
National Oceanic & Atmospheric Administration	5.8	6.2	6.4	2.4	1.4	1.3	1.2	0.9[a]	167	48
Interior	20.0	22.0	20.9	20.3	19.4	19.2	6.2	6.2	3	27
Geological Survey[b]	19.6	21.7	20.8	20.2	19.4	18.4	5.6	5.1	3	32
National Aeronautics & Space Administration	17.8	15.4	13.4	11.8	16.3	7.3	9.4	6.2	13	17
Others	6.6	6.9	2.4	6.3	1.5	3.3	6.1	5.6	−63	−16
TOTAL	$704.6	$677.1	$680.3	$662.4	$644.5	$606.4	$520.3	$481.2	3%	7%
ANNUAL CHANGE	4%	0%	3%	3%	6%	17%	8%	−1%		

Note: Fiscal years. a Estimated. b Includes Office of Water Research & Technology. **Source:** National Science Foundation

In 1989, but for chemical engineering 90% of funds come from Defense, Energy, NSF, and EPA

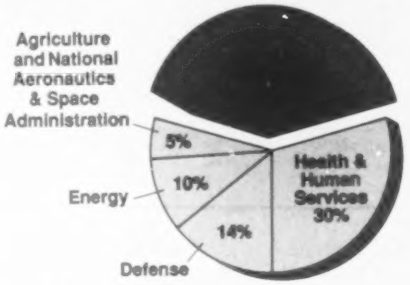
1987	1986			1985			1984		
Metallurgy & materials	All engineering	Chemical engineering	Metallurgy & materials	All engineering	Chemical engineering	Metallurgy & materials	All engineering	Chemical engineering	Metallurgy & materials
$ 19.9	$1066.9	$ 1.0	$ 16.2	$ 931.6	$ 0.6	$ 15.8	$ 967.8	$ 0.3	$ 14.2
203.6	1505.6	50.3	253.7	1502.0	53.3	260.9	1488.4	38.4	180.3
34.5	444.7	1.9	33.4	423.9	1.7	28.6	439.5	3.5	30.3
57.2	397.8	24.4	117.4	421.2	24.8	121.1	398.4	11.3	53.9
32.1	373.6	24.0	26.8	344.3	26.7	42.2	324.8	23.5	35.5
79.8	289.5	0	76.2	312.6	0.1	69.0	325.7	0.2	60.6
77.1	494.2	121.6	82.8	511.3	136.6	68.4	439.0	46.1	68.7
22.9	199.1	33.4	43.5	193.3	32.6	42.7	164.9	27.7	27.3
0.7	52.8	1.9	1.8	49.4	0.6	1.5	51.1	1.2	1.9
28.5	93.2	4.7	38.5	100.2	4.8	39.8	111.4	4.5	42.2
0.5	48.6	23.9	0.5	44.8	18.0	2.6	37.8	17.8	0
8.6	41.7	2.6	7.6	39.8	1.7	6.9	35.3	1.8	6.4
0	31.1	6.0	0	28.7	5.6	0	56.7	6.4	0
0.2	205.9	0.4	0.5	227.4	0.3	0.5	271.7	0.3	0.1
$362.0	$3738.9	$245.8	$445.0	$3628.5	$254.1	$439.1	$3624.1	$144.5	$341.1
−19%	3%	−3%	1%	0%	76%	29%	3%	0%	3%

Four agencies each provide about a fifth of federal funds for all chemical research . . .



Estimated fiscal 1989 federal chemistry research obligations = $705 million

. . . but NSF clearly dominates support for chemical research at universities



Estimated fiscal 1989 federal chemistry university research obligations = $315 million[a]

[a] Total is for these six agencies only. **Source:** National Science Foundation

UNIVERSITY RESEARCH: Overall growth has outpaced that for chemistry

Federal obligations, $ millions	1989[a]	1988[a]	1987	1986	1985	1984	1983	1982	Annual change 1986–87	Annual change 1982–87
Life sciences	$4233	$4072	$3824	$3252	$3192	$2800	$2460	$2205	18%	12%
Physical sciences	955	852	823	752	750	698	597	559	9	8
Chemistry	315	291	281	266	267	242	206	190	6	8
Physics	460	418	404	405	402	375	329	306	0	6
Engineering	679	685	600	609	507	474	409	362	−2	11
Chemical	51	60	55	51	46	51	24	19	7	23
Metallurgy and materials	156	176	108	133	107	88	86	75	−19	7
Environmental sciences	462	412	400	366	361	320	317	275	9	8
Mathematical and computer sciences	397	319	289	274	253	182	172	140	5	16
Other sciences	479	460	449	365	348	304	298	256	23	12
TOTAL	$7205	$6802	$6384	$5617	$5411	$4777	$4252	$3796	14%	11%
ANNUAL CHANGE	6%	7%	14%	4%	13%	12%	12%	2%		

Note: Fiscal years. Includes funding only from six agencies that together represent approximately 97% of federal research support to universities. a Estimated. **Source:** National Science Foundation

UNIVERSITY RESEARCH IN CHEMISTRY: Funding is dominated by NSF, NIH, and DOD

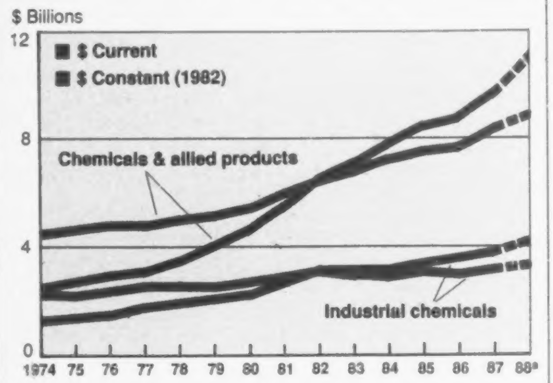
Federal obligations, $ millions	1989[a]	1988[a]	1987	1986	1985	1984	1983	Annual change 1986–87	Annual change 1983–87
National Science Foundation	$128.1	$107.8	$107.1	$103.5	$106.1	$100.7	$ 84.7	4%	6%
Health & Human Services	94.1	91.0	85.0	75.0	75.2	63.2	51.9	13	13
National Institutes of Health	92.5	89.4	83.4	74.4	74.7	62.8	51.4	12	13
Alcohol, Drug Abuse & Mental Health Administration	1.6	1.6	1.6	0.6	0.6	0.4	0.5	172	37
Defense	45.1	42.4	45.0	43.2	40.4	34.7	29.1	4	11
Air Force	18.2	16.6	18.4	16.1	14.0	na	9.6	14	18
Navy	17.1	16.3	17.2	13.9	15.5	na	11.7	24	10
Army	6.5	7.0	8.3	12.4	10.9	na	7.8	−33	1
Defense agencies	3.2	2.5	1.1	0.9	0	na	0	28	—
Energy	32.0	32.6	28.5	27.6	26.0	26.3	18.6	3	11
Agriculture	10.6	12.6	11.2	12.2	15.5	13.5	14.5	−8	−6
National Aeronautics & Space Administration	4.9	4.8	4.3	4.2	4.1	4.1	4.6	2	−2
TOTAL	$314.8	$291.3	$281.1	$265.7	$269.4	$242.3	$205.7	6%	8%
ANNUAL CHANGE	8%	4%	6%	−1%	11%	18%	na		

Note: Fiscal years. Data from these six agencies represent approximately 97% of federal obligations for 1989. a Estimated. na = not available. **Source:** National Science Foundation

3 R&D Industry

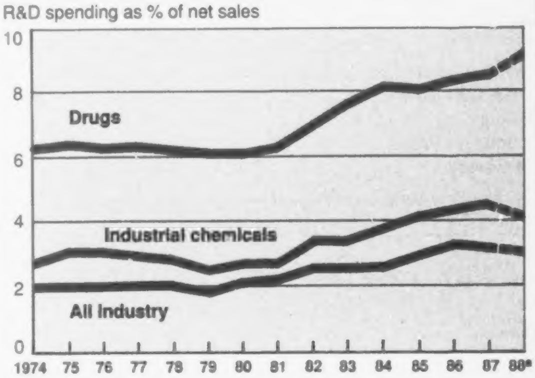
Strong Drug Company R&D Sets Pace

R&D spending for all chemicals has outpaced inflation for over a decade



Note: Constant-dollar values calculated by C&EN based on NSF data.
a C&EN estimates. **Source:** National Science Foundation

Drug firms continue growth in share of revenue supporting R&D



a C&EN estimates. **Source:** National Science Foundation

TOTAL FUNDS FOR INDUSTRIAL R&D: Chemical industry R&D topped $10 billion last year

												Annual change	
$ Millions	**1988a**	**1987**	**1986**	**1985**	**1984**	**1983**	**1982**	**1981**	**1980**	**1979**	**1978**	**1977**	**1986–87**	**1977–87**
Chemicals and allied products	$ 11,000	$ 9,831	$ 8,837	$ 8,540	$ 7,927	$ 7,185	$ 6,604	$ 5,625	$ 4,636	$ 4,038	$ 3,580	$ 3,202	11%	12%
Industrial chemicals	4,200	3,879	3,552	3,498	3,240	3,214	3,206	2,602	2,197	1,962	1,798	1,668	9	9
Drugs	4,800	4,091a	3,656	3,490a	3,316a	2,901a	2,481a	2,073a	1,777a	1,517	1,308	1,117	12	14
Other chemicals	2,000	1,861a	1,628	1,552a	1,371a	1,070a	917a	750a	662a	559	474	417	14	16
Other industries	91,000	86,474	81,059	77,070	68,160	$58,509	52,406	46,185	39,869	34,198	29,724	26,623	7	13
TOTAL	$102,000	$96,305	$89,896	$85,610	$76,087	$65,694	$59,010	$51,810	$44,505	$38,226	$33,304	$29,825	7%	12%

a C&EN estimates. **Source:** National Science Foundation

COMPANY FUNDS FOR INDUSTRIAL R&D: Strong rebound in 1987 after slow growth in 1986

											Annual change	
$ Millions	**1987**	**1986**	**1985**	**1984**	**1983**	**1982**	**1981**	**1980**	**1979**	**1978**	**1977**	**1986–87**	**1977–87**
Chemicals and allied products	$ 9,638	$ 8,656	$ 8,310	$ 7,736	$ 6,792	$ 6,197	$ 5,205	$ 4,264	$ 3,692	$ 3,250	$ 2,907	11%	13%
Industrial chemicals	3,691	3,374	3,281	3,057	2,828	2,810	2,393	1,856	1,617	1,473	1,387	9	10
Drugs	4,088	3,654	3,481	3,310	2,896	2,473	2,064	1,756	1,516a	1,304a	1,107a	12	14
Other chemicals	1,859	1,628	1,546	1,369	1,068	914	747	653	559a	473a	413a	14	16
Other industries	55,264	53,069	50,170	44,995	38,245	34,279	30,223	26,212	22,016	18,865	16,433	4	13
TOTAL	$64,902	$61,725	$58,480	$52,731	$45,037	$40,476	$35,428	$30,476	$25,708	$22,115	$19,340	5%	13%

a C&EN estimates. **Source:** National Science Foundation

FEDERAL FUNDS FOR INDUSTRIAL R&D: Modest as usual for chemicals but up a bit in 1987

$ Millions	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	Annual change 1986–87	Annual change 1977–87
Chemicals and allied products	$ 193	$ 181	$ 230	$ 191[a]	$ 393	$ 407	$ 421	$ 372	$ 346	$ 330	$ 295	7%	−4%[a]
Industrial chemicals	188	179	217	183[a]	386	396	409	341	345	325	281	5	−4[a]
Drugs and other chemicals	5	2	13	8	7	11	12	31	1	5	14	—	—
Other industries	31,210	27,990	26,900	23,165	20,264	18,127	15,961	13,657	12,172	10,859	10,190	12	12
TOTAL	$31,403	$28,171	$27,130	$23,356	$20,657	$18,534	$16,382	$14,029	$12,518	$11,189	$10,485	11%	12%

a The decline in 1984 from 1983 results from the administration of federally funded Oak Ridge National Laboratory being changed from a chemical company to a company in the aircraft and missile industry. **Source:** National Science Foundation

COST PER INDUSTRIAL R&D SCIENTIST OR ENGINEER: Chemicals catch up with all industry

$ Thousands	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977
Chemicals and allied products	$132.9	$118.8	$116.3	$112.5	$104.8	$102.5	$ 96.6	$ 87.4	$79.6	$72.8	$67.6
Industrial chemicals	163.0	114.1	114.6	132.0	123.1	122.1	118.0	103.4	92.8	84.2	79.6
Drugs	a	119.9	a	a	103.1	a	a	79.2	71.4	64.8	59.9
Other chemicals	a	84.6	a	a	a	a	a	66.5	66.5	61.6	53.8
All industry	$132.7	$130.3	$131.4	$125.5	$116.4	$112.2	$103.9	$ 94.9	$87.4	$80.4	$75.8

a Not separately available but included in chemicals and allied products. **Source:** National Science Foundation

R&D BY U.S. COMPANIES ABROAD: Chemical companies substantially boost foreign R&D

$ Millions	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	Annual change 1986–87	Annual change 1977–87
Chemicals and allied products	$1265	$1071	$ 843	$ 786	$ 729	$ 682	$ 715	$ 603	$ 500	$ 395	$ 332	18%	14%
Industrial and other chemicals	684	579	444	385	368	319	287	246	199	151	133	18	18
Drugs	581	492	399	401	361	363	428	357	301	244	199	18	11
Other industries	3756	3580	2807	2847	2540	2412	2679	2562	2254	1814	1545	5	9
TOTAL	$5021	$4651	$3650	$3633	$3269	$3094	$3393	$3165	$2754	$2209	$1877	8%	10%

Source: National Science Foundation

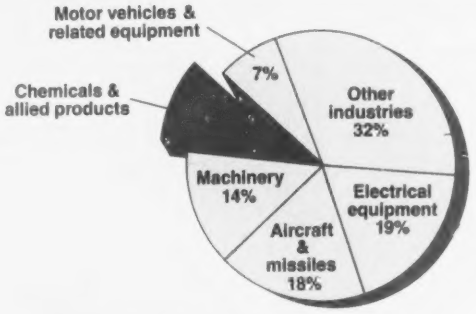
CHEMICAL R&D SPENDING: Biggest programs got biggest boosts in 1988

$ Millions	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1988 R&D spending as % of sales
Du Pont	$1319	$1223	$1156	$1144	$1097	$ 966	$ 879	$ 718	$ 591	$ 509	$ 461	4.0%
Dow Chemical	772	670	605	547	507	492	460	404	314	269	232	4.6
Monsanto	648	615	596	470	370	290	264	233	208	161	136	7.8
American Cyanamid	365	314	278	251	232	208	185	166	148	130	108	7.9
Union Carbide[a]	159	159	148	275	265	245	240	207	166	161	156	1.9
Rohm & Haas	156	142	133	124	109	100	92	77	67	54	49	6.2
W. R. Grace	119	107	94	92	81	73	64	57	45	42	37	2.1
Hercules	74	74	71	76	72	74	74	65	57	50	43	2.6
Lubrizol	65	62	51	44	33	37	36	33	28	23	21	5.8
Olin	58	62	56	53	52	49	45	38	31	26	25	2.5
Air Products	72	57	61	51	44	40	37	32	30	24	23	3.0
Ethyl	59	50	47	47	40	39	39	37	34	29	25	2.9
International Flavors	50	45	39	34	32	32	31	30	29	27	24	6.0
Nalco Chemical	37	35	33	32	32	30	33	30	28	21	17	3.7
Pennwalt	31	45	45	39	36	33	31	27	24	22	23	3.0
TOTAL	$3984	$3660	$3413	$3279	$3002	$2708	$2510	$2154	$1800	$1548	$1380	4.3%
ANNUAL CHANGE	9%	7%	4%	9%	11%	8%	17%	20%	16%	12%	13%	

Note: Prior years not restated to reflect company revisions. a Union Carbide divested a substantial part of its business in 1986; on a pro forma basis, R&D spending was $181 million in 1985 and $178 million in 1984. **Source:** Company data

3 R&D Industry

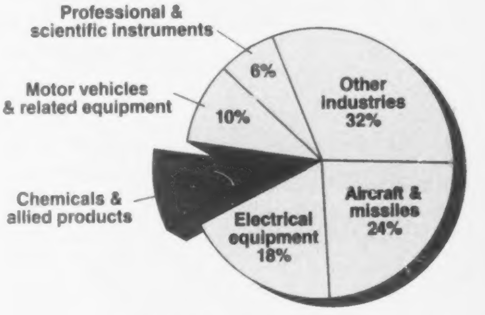
One tenth of scientists and engineers in industry work for chemical companies…



1988 total industrial R&D scientists and engineers[a] = 725,800

a Full-time equivalent as of January 1988. **Source:** National Science Foundation

…and those companies perform a tenth of all industrial R&D in the U.S.



1988 total industrial R&D expenditures = $96.3 million

R&D SCIENTISTS AND ENGINEERS IN INDUSTRY: Industrial chemical firms show decline

												Annual change	
Thousands	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1987–88	1978–88
Chemicals and allied products	**74.9**	**73.0**	**75.8**	**71.1**	**69.8**	**67.3**	**61.6**	**54.7**	**51.4**	**50.0**	**48.3**	**3%**	**4%**
Industrial chemicals	23.2[a]	24.4	24.9	23 5	25.6	26.6	25.9	21.6	20.9	21.4	21.3	−5	1
Drugs	31.2	29.2	31.8	30.8	30.8[a]	28.2	25.6	23.3	21.6	20.8	19.5	7	5
Other chemicals	20.5	19.4	19.1	16.7	13.4	12.1	10.1	9.8	8.9	7.8	7.5	6	11
Other industries	**650.9**	**630.8**	**600.7**	**555.1**	**516.7**	**474.6**	**448.2**	**433.1**	**399.2**	**373.9**	**356.1**	**3**	**6**
TOTAL	**725.8**	**703.8**	**676.5**	**626.2**	**586.5**	**541.9**	**509.8**	**487.8**	**450.6**	**423.9**	**404.4**	**3%**	**6%**

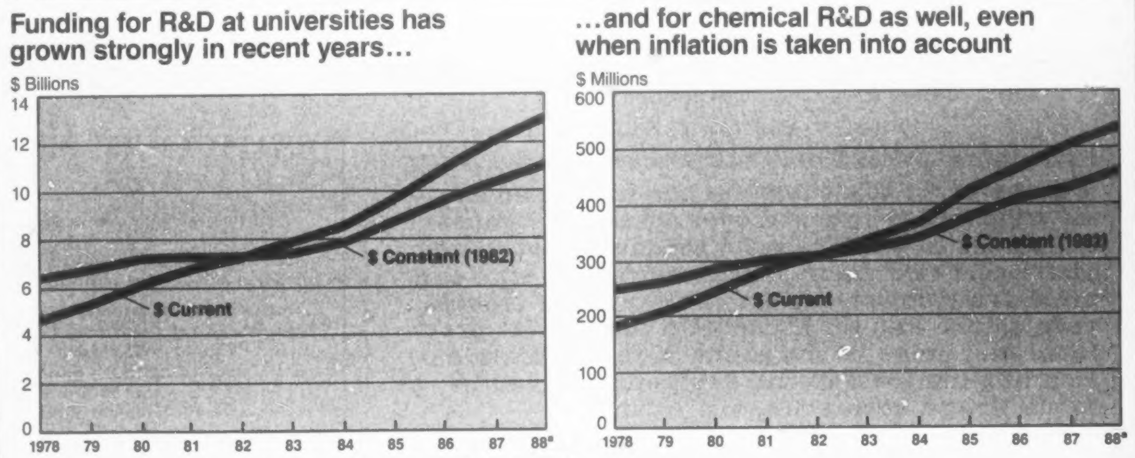
Note: Data as of January of each year for full-time-equivalent personnel. a C&EN estimates. **Source:** National Science Foundation

CHEMISTS IN INDUSTRY: 40% work in pharmaceutical, specialty, or basic chemical firms

	% of industrial chemists				Mean salary ($ thousands)[a]		
Industry	All chemists	B.S.	M.S.	Ph.D.	B.S	M.S.	Ph.D.
Pharmaceuticals[b]	18%	16%	21%	19%	$42.4	$50.7	$64.9
Specialty chemicals	15	15	14	16	45.7	51.3	61.6
Basic chemicals	7	4	5	9	46.3	50.0	64.6
Plastics	6	6	5	7	46.2	52.2	64.2
Electronics	5	4	5	5	46.2	52.5	62.2
Petroleum and natural gas	4	4	3	5	44.4	56.3	69.5
Food	4	5	4	3	41.5	49.6	59.9
Coatings	4	6	4	3	41.6	48.5	56.3
Agricultural chemicals	3	3	3	4	37.5	47.3	62.2
Metals and minerals	2	3	3	1	39.6	46.1	56.1
Biochemical products	2	1	2	3	38.7	52.7	61.1
Rubber	2	2	1	1	45.5	50.8	57.1
Soaps and detergents	1	2	1	1	39.4	53.4	57.3
Paper	1	1	1	1	41.8	44.7	54.4
Other manufacturing	15	15	16	14	42.1	50.5	58.9
Nonmanufacturing	10	14	12	7	39.0	48.2	61.2

a As of March 1, 1989; to facilitate comparison, mean salaries are adjusted for differences in average length of experience for each group. b Includes personal care products.
Source: ACS survey

Universities Fastest Growing R&D Sector



Note: Data for institutional fiscal years. **a** C&EN estimates. **Source:** National Science Foundation

CHARACTER OF UNIVERSITY R&D SPENDING: Nearly 70% goes for basic research

												Annual change	
$ Millions	**1987**	**1986**	**1985**	**1984**	**1983**	**1982**	**1981**	**1980**	**1979**	**1978[a]**	**1977**	**1986–87**	**1977–87**
Basic research	$ 8,301	$ 7,512	$6556	$5731	$5324	$4883	$4589	$4024	$3612	$3176	$2800	11%	11%
Applied research	3,125[b]	2,828[b]	2584[b]	2413[b]	2119[b]	2023[b]	1877[b]	1693[b]	1465	1213	1067	11	11
Development	655[b]	586[b]	554[b]	479[b]	440[b]	418[b]	379[b]	344[b]	284	236	200	12	13
TOTAL	**$12,082**	**$10,926**	**$9695**	**$8623**	**$7884**	**$7324**	**$6845**	**$6062**	**$5361**	**$4625**	**$4067**	11%	12%
ANNUAL CHANGE	11%	13%	12%	9%	8%	7%	13%	13%	16%	14%	9%		

Note: Data for institutional fiscal years. Data since 1980 were revised in 1987. **a** NSF estimates, based on data from Ph.D.-granting institutions only. **b** C&EN estimates.
Source: National Science Foundation

SOURCE OF UNIVERSITY R&D FUNDS: Schools' own funds support 18% of R&D effort

												Annual change	
$ Millions	**1987**	**1986**	**1985**	**1984**	**1983**	**1982**	**1981**	**1980**	**1979**	**1978[a]**	**1977**	**1986–87**	**1977–87**
Federal government	$ 7,326	$ 6,713	$6064	$5425	$4980	$4759	$4561	$4096	$3595	$3059	$2726	9%	10%
Institutional funds	2,126	1,877	1632	1424	1315	1122	1009	835	728	623	514	13	15
State and local governments	1,019	911	745	684	622	613	546	491	470	414	374	12	11
Industry	777	692	559	474	388	339	293	238	194	170	139	12	19
Other sources	834	732	694	617	579	491	436	401	374	359	314	14	10
TOTAL	**$12,082**	**$10,926**	**$9695**	**$8623**	**$7884**	**$7324**	**$6845**	**$6062**	**$5361**	**$4625**	**$4067**	11%	12%

Note: Data for institutional fiscal years. Data since 1980 were revised in 1987. **a** NSF estimates, based on data from Ph.D.-granting institutions only. **Source:** National Science Foundation

FIELDS OF UNIVERSITY R&D SPENDING: Support for science R&D tops $10 billion in 1987

$ Millions	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978ᵃ	1977	Annual change 1986–87	Annual change 1977–87
All sciences	$10,193	$ 9,284	$8275	$7400	$6761	$6291	$5877	$5196	$4593	$4024	$3569	10%	11%
Life	6,478	5,895	5278	4716	4308	4015	3695	3218	2833	2538	2259	10	11
Physical	1,379	1,282	1148	996	901	824	767	678	602	469	424	8	13
Physics	658	628	550	471	417	367	357	322	292	235	202	5	13
Chemistry	508	468	422	370	336	309	286	245	206	183	159	8	12
Environmental	832	780	709	651	618	559	550	509	453	379	319	7	10
Psychology and social	684	628	545	511	486	490	499	453	396	367	353	9	7
Computer	370	318	281	224	176	149	133	114	98	67	56	16	21
Mathematical	180	153	130	125	108	98	69	79	79	59	52	18	13
Others	268	227	185	178	165	156	145	146	134	117	106	18	10
Engineering	1,889	1,642	1419	1223	1122	1033	968	866	768	601	499	15	14
Chemical	140	126	109	95	91	83	84	68	na	na	na	12	—
TOTAL	$12,082	$10,926	$9695	$8623	$7884	$7324	$6845	$6062	$5361	$4625	$4067	11%	12%
ANNUAL CHANGE	11%	13%	12%	9%	8%	7%	13%	13%	15%	14%	9%		

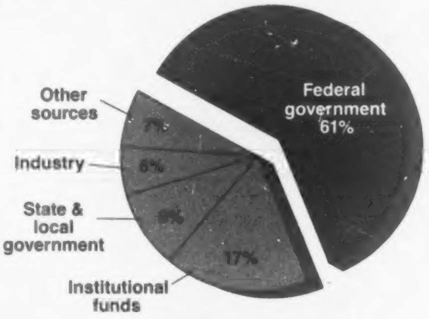
Note: Data for institutional fiscal years. Data since 1980 were revised in 1987. a NSF estimates, based on data from Ph.D.-granting institutions only. **na** = not available.
Source: National Science Foundation

FEDERALLY FINANCED R&D SPENDING AT UNIVERSITIES: Slower growth for chemistry

$ Millions	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978ᵃ	1977	Annual change 1986–87	Annual change 1977–87
All sciences	$6214	$5733	$5196	$4643	$4241	$4062	$3899	$3500	$3069	$2651	$2389	8%	10%
Life	3826	3498	3188	2831	2587	2503	2365	2094	1819	1626	1474	9	10
Physical	1041	983	890	780	700	649	619	555	491	392	339	6	12
Physics	526	511	453	390	342	306	309	280	253	199	172	3	12
Chemistry	365	339	312	278	248	230	217	190	157	138	122	8	12
Environmental	546	521	478	451	427	392	392	372	329	275	239	5	9
Psychology and social	291	281	260	241	236	250	280	263	227	204	202	3	4
Computer	253	229	193	161	128	107	93	77	69	41	38	10	21
Mathematical	131	113	96	91	76	72	68	61	60	44	41	16	12
Others	126	108	91	87	87	88	82	78	73	68	58	17	8
Engineering	1112	980	869	782	739	698	663	596	526	408	337	13	13
Chemical	70	67	58	54	52	50	56	46	na	na	na	5	—
TOTAL	$7326	$6713	$6064	$5425	$4980	$4759	$4561	$4096	$3595	$3059	$2726	9%	10%
ANNUAL CHANGE	9%	11%	12%	9%	5%	4%	11%	14%	18%	12%	9%		

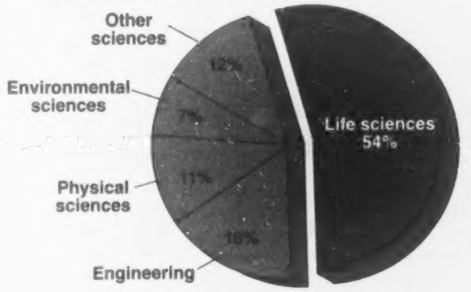
Note: Data for institutional fiscal years. Data since 1980 were revised in 1987. a NSF estimates, based on data from Ph.D.-granting institutions only. **na** = not available.
Source: National Science Foundation

Three fifths of academic R&D support comes from the federal government…



Fiscal 1987 academic R&D expenditures = $12.1 billion

…and more than half is spent in the life sciences



Fiscal 1987 academic R&D expenditures = $12.1 billion

Source: National Science Foundation

TOP 10 UNIVERSITY R&D CENTERS: Los Alamos spends most on physical sciences R&D

$ Millions, fiscal 1987	Physical sciences	Engineering	Math & computer sciences	Environmental sciences	Life sciences	Psychology & social sciences	Other sciences	Total
1 **Jet Propulsion Lab**	$ 107.3	$ 388.7	$329.6	$ 89.9	$ 0	$ 0	$0	**$ 915.5**
2 **Lawrence Livermore Lab**	271.8	457.8	129.4	30.3	25.5	0	0	**914.8**
3 **Los Alamos National Lab**	405.3	283.3	77.9	21.0	27.2	17.8	2.8[a]	**835.3**
4 **Lincoln Lab**	67.9	249.7	35.7	0	0	0.4	0	**353.7**
5 **Argonne National Lab**	86.5	130.7	4.1	43.2	12.0	0	0	**276.6**
6 **Brookhaven National Lab**	156.1	33.7	0.8	9.2	18.7	2.0	0	**220.5**
7 **Lawrence Berkeley Lab**	105.6	16.8	5.6	18.0	30.6	0	1.4	**178.1**
8 **Fermi National Accelerator Lab**	164.5	0	0	0	2.6	0	0	**167.1**
9 **Plasma Physics Lab**	107.2	0	0	0	0	0	0	**107.2**
10 **Stanford Linear Accelerator Center**	89.0	0	0	0	0	0	0	**89.0**
All others	69.2	3.0	14.2	50.1	5.5	2.1	0	**144.1**
TOTAL, ALL FEDERALLY FUNDED R&D CENTERS	**$1630.5**	**$1563.8**	**$597.2**	**$261.7**	**$122.3**	**$22.3**	**$4.2**	**$4202.0**

Note: Data for university-administered, federally funded R&D centers. A number of institutions have developed or are in the process of developing new computer systems and methodologies that enable them to report more accurately the total cost of science and engineering research. Fiscal 1986 comparisons with data reported in earlier years may be inappropriate in some areas.
a Estimated. **Source:** National Science Foundation

CAPITAL SPENDING AT UNIVERSITIES: Physical sciences get strong federal support

$ Millions	1987 Total spending	1987 % federal funds	1986	1985	1984	1983	1982	Annual change 1986–87	Annual change 1982–87
All sciences	**$1390.6**	9%	**$1206.9**	**$1067.6**	**$1069.9**	**$ 962.1**	**$824.7**	15%	11%
Life sciences	944.6	6	797.5	712.3	740.8	678.4	590.4	18	10
Physical sciences	156.1	23	142.4	119.6	114.7	96.8	82.1	10	14
Mathematical and computer sciences	81.4	12	89.6	76.8	49.6	52.9	34.3	−9	19
Psychology and social sciences	66.1	6	69.2	75.7	87.1	57.4	43.6	−4	9
Environmental sciences	51.5	23	46.8	53.8	36.7	41.0	42.4	10	4
Other sciences	91.0	14	61.5	29.4	41.0	35.7	31.9	48	23
Engineering	**389.2**	10	**309.9**	**182.4**	142.0	134.5	144.5	26	22
TOTAL	**$1779.8**	9%	**$1516.8**	**$1249.9**	**$1211.8**	**$1096.6**	**$969.1**	17%	13%
ANNUAL CHANGE	17%	—	21%	3%	11%	13%	20%		

Note: Data for institutional fiscal years. Includes expenditures for facilities and equipment for research, development, and instruction. **Source:** National Science Foundation

UNIVERSITY SPENDING FOR RESEARCH EQUIPMENT: Growing strongly for chemistry

$ Millions	1987 Total	1987 Federal funds	1986 Total	1986 Federal funds	1980 Total	1980 Federal funds	Annual change 1986–87 Total	Annual change 1986–87 Federal funds	Annual change 1980–87 Total	Annual change 1980–87 Federal funds
All sciences	**$660.5**	**$425.1**	**$636.2**	**$420.1**	**$277.8**	**$185.1**	4%	1%	**19%**	**18%**
Life sciences	**333.6**	**187.9**	**327.6**	**187.2**	**170.0**	**109.1**	2	0	**14**	**11**
Physical sciences	**164.5**	**129.7**	**163.0**	**131.5**	**54.0**	**44.4**	1	−1	**25**	**24**
Physics	79.2	65.6	89.3	76.8	25.6	22.7	−11	−15	25	24
Chemistry	66.6	49.5	59.7	44.3	23.6	18.1	12	12	23	22
Mathematical and computer sciences	**56.8**	**45.6**	**51.5**	**42.7**	**9.8**	**4.6**	10	7	**42**	**59**
Environmental sciences	**56.1**	**36.7**	**52.5**	**36.8**	**24.5**	**16.2**	7	0	**18**	**18**
Other sciences	**49.5**	**25.8**	**41.7**	**21.8**	**19.6**	**10.8**	19	18	**20**	**19**
Engineering	**172.0**	**99.1**	**142.2**	**82.1**	**55.6**	**35.0**	21	21	**25**	**23**
Chemical	14.5	7.5	13.2	7.4	4.7	2.8	10	1	25	21
TOTAL	**$832.5**	**$524.7**	**$778.3**	**$502.2**	**$333.5**	**$220.1**	7%	4%	**20%**	**19%**

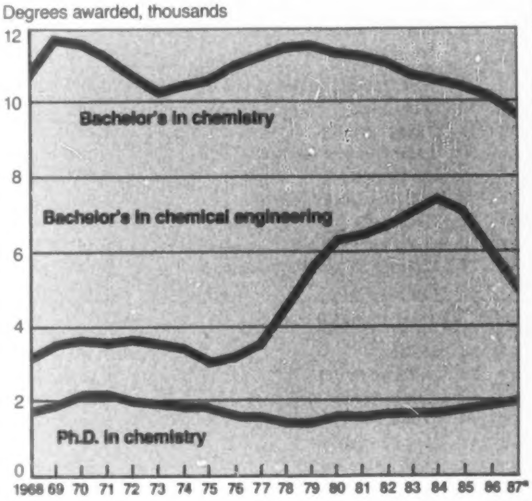
Note: Data for institutional fiscal years. **Source:** National Science Foundation

CHEMICAL DEGREES: Bachelor's degrees in chemistry set 20-year low

Academic year	Degrees awarded in chemistry			Degrees awarded in chemical engineering		
	Bachelor's	Master's	Ph.D.	Bachelor's	Master's	Ph.D.
1968	10,847	2014	1757	3211	1156	367
1969	11,807	2070	1941	3557	1136	409
1970	11,617	2146	2208	3720	1045	438
1971	11,183	2284	2160	3615	1100	406
1972	10,721	2259	1971	3663	1154	394
1973	10,226	2230	1882	3636	1051	397
1974	10,525	2138	1828	3454	1045	400
1975	10,649	2006	1824	3142	990	346
1976	11,107	1796	1623	3203	1031	308
1977	11,322	1775	1571	3581	1086	291
1978	11,474	1892	1525	4615	1237	259
1979	11,643	1765	1518	5655	1149	304
1980	11,446	1733	1551	6383	1271	284
1981	11,347	1654	1622	6527	1267	300
1982	11,062	1751	1722	6740	1285	311
1983	10,746	1604	1746	7145	1304	319
1984	10,704	1667	1744	7475	1514	330
1985	10,482	1719	1789	7146	1544	418
1986	10,116	1754	1908	5877	1361	446
1987ᵃ	9,661	1738	1976	4983	1184	497

a Preliminary figures. **Source:** National Center for Education Statistics

Only Ph.D. degrees are increasing



Note: Academic years. **a** Preliminary figures.
Source: National Center for Education Statistics

TOP 10 UNIVERSITIES IN R&D SPENDING: Johns Hopkins, MIT lead for physical sciences

$ Millions, fiscal 1987	Physical sciences	Chemistryᵃ	Engineering	Environmental sciences	Life sciences	Math & computer sciences	Other sciences	Total
1 **Johns Hopkins U**	$ 79.4	$ 5.6	$ 172.8	$ 28.0	$ 136.2	$ 80.9	$ 13.7	**$ 510.9**
2 **Massachusetts Institute of Technology**	78.8	11.5	110.8	10.6	32.8	13.0	18.3	**264.4**
3 **U of Wisconsin, Madison**	25.4	7.0	30.1	19.6	144.7	7.2	27.6	**254.5**
4 **Cornell U**	41.3	8.1	35.1	5.9	134.4	16.3	11.8	**244.8**
5 **Stanford U**	45.1	8.9	68.0	4.3	103.1	15.0	5.4	**240.9**
6 **U of Michigan**	15.2	3.3	35.9	14.0	113.5	5.7	40.7	**224.9**
7 **U of Minnesota**	12.5	5.4	23.2	5.8	162.1	5.4	13.5	**222.4**
8 **Texas A&M U**	16.6	7.5	33.4	48.4	103.3	4.6	13.6	**219.9**
9 **U of California, Los Angeles**	20.9	10.1	19.9	11.6	107.5	6.9	21.9	**188.8**
10 **U of Illinois, Urbana**	21.8	9.0	51.8	21.3	42.9	17.0	33.9	**188.7**
TOTAL, FIRST 10 INSTITUTIONS	**$ 356.9**	**$ 76.4**	**$ 581.0**	**$169.5**	**$1080.5**	**$171.9**	**$200.4**	**$ 2,560.2**
TOTAL, ALL INSTITUTIONS	**$1378.7**	**$507.8**	**$1888.7**	**$832.0**	**$6478.5**	**$550.6**	**$952.6**	**$12,081.5**

Note: Data for institutional fiscal years. A number of institutions have developed or are in the process of developing new computer systems and methodologies that enable them to report more accurately the total cost of science and engineering research. Fiscal 1987 comparisons with data reported in earlier years may be inappropriate in some areas. **a** Included in physical sciences.
Source: National Science Foundation

SCHOOLS SPENDING MOST ON CHEMICAL R&D: Five spent more than $10 million in 1987

Rank 1987	Rank 1986		1987 Total spending ($ thousands)	1987 % federal funds	1986 ($ thousands)	1985 ($ thousands)	1984 ($ thousands)	1983 ($ thousands)	1982 ($ thousands)	Annual change 1986–87	Annual change 1982–87
1	3	**U of California, Berkeley**	$ 12,490	89%	$ 9,114	$ 10,804	$ 7,850	$ 7,945	$ 6,283	37%	15%
2	1	**Massachusetts Inst. of Technology**	11,471	93	13,593	13,221	11,741	8,914	9,792	−16	3
3	5	**U of Texas, Austin**	11,420	56	8,531	7,908	6,639	5,938	4,843	34	19
4	2	**California Inst. of Technology**	10,870	91	9,176	7,605	6,446	6,994	6,136	18	12
5	7	**U of California, Los Angeles**	10,099	93	7,954	7,243	7,219	5,496	5,187	27	14
6	8	**U of Maryland, College Park**	9,258	44	7,904	7,289	6,324	6,333[a]	4,718[a]	17	14
7	4	**U of Illinois, Urbana**	9,035	70	8,604	7,079	6,284	5,886	6,422	5	7
8	6	**Stanford U**	8,916	89	8,340	8,354	6,809	6,375	5,564	7	10
9	14	**Harvard U**	8,895	93	7,202	6,557[a]	6,307[a]	6,898[a]	5,512[a]	24	10
10	11	**Cornell U**	8,095	83	7,376	7,962	6,710	5.717[a]	6.239[a]	10	5
		Total, first 10 institutions	$100,549	80%	$ 87,794	$ 84,022	$ 72,329	$ 66,496	$ 60,696	15%	11%
11	15	**U of Massachusetts, Amherst**	7,589	66	6,967	6,420	6,347	5,162	4,364	9	12
12	10	**U of Chicago**	7,514	86	7,553[a]	6,921[a]	5,735	4,798	4,396	−1	11
13	13	**Texas A&M U**	7,462	54	7,230[a]	6,768[a]	5,606[a]	4,963	4,521	3	11
14	60	**Case Western Reserve U**	7,164	70	2,922[a]	2,802	2,759	2,232	2,185	145	27
15	19	**Purdue U**	7,092	84	6,315	6,018	5,443	4,542	4,459	12	10
16	9	**U of Wisconsin, Madison**	6,984	68	7,892	7,350	6,076	5,310	4,567	−12	9
17	12	**Rockefeller U**	6,823	48	7,335	4,826[a]	1,178	919	—	−7	—
18	22	**U of Pennsylvania**	6,741	84	6,064	5,025	4,375	4,982	3,068	11	17
19	25	**Columbia U, main division**	6,715	99	5,555	5,188	4,662	4,281	4,700	21	7
20	24	**Princeton U**	6.477	78	5,702	3,963	3,670	3,509	3,062	14	16
		Total, first 20 institutions	$171,110	78%	$151,329	$139,303	$118,180	$107,194	$ 96,018[b]	13%	12%
21	21	**Indiana U**	6,181	80	6,110	5,820	5,642	5,551	5,341	1	3
22	33	**Northwestern U**	6,095	76	4,826	5,062	4,557	3,413	3,026	26	15
23	18	**Pennsylvania State U**	6,072	81	6,438	6,509	5,124	4,729	3,564	−6	11
24	16	**Ohio State U**	5,755	78	6,546	5,422	4,104	3,739	2,907	−12	15
25	34	**U of Florida**	5,690	61	4,750	4,380	4,024	2,347	2,248	20	20
26	26	**Johns Hopkins U**	5,593	91	5,506	4,612[a]	4,030	4,592[a]	4,721	2	3
27	27	**U of Notre Dame**	5,550	93	5,402	5,549	4,760	4,022	4,020	3	7
28	20	**Yale U**	5,538	89	6,169[a]	5,600[a]	4,134	3,341	2,875	−10	14
29	30	**U of Minnesota**	5,426	81	5,110	4,167	4,067	4,047	4,297	6	5
30	17	**U of California, San Diego**	5,179	89	6,535	4,642	4,355	3,910	3,894	−21	6
		Total, first 30 institutions	$228,189	79%	$208,721	$191,066	$162,977	$146,885	$132,911[b]	9%	11%
31	23	**U of Colorado**	5,118	86	5,830	6,360	4,134	3,302	3,492	−12	8
32	32	**U of Pittsburgh**	5,105	79	4,974	4,580	3,965	3,267	2,714	3	13
33	29	**Georgia Inst. of Technology**	4,889	52	5,260	3,684	3,846	3,401	3,327	−7	8
34	28	**U of Utah**	4,846	87	5,354	4,840	3,830	3,638	3,364	−9	8
35	35	**U of South Carolina**	4,622	67	4,432	3,850	3,423	2,721	2,483	4	13
36	31	**U of Oregon, main campus**	4,462	80	5,087	4,640	4,255	3,351	2,971	−12	8
37	37	**Lehigh U**	4,410	42	4,237	3,456	3,361	3,664	2,584	4	11
38	43	**Virginia Polytechnic Inst. & State U**	4,190	55	3,786	3,417	2,686	2,206	1,740	11	19
39	49	**U of Virginia**	4,169	79	3,436	3.046	2,516	2,069	1,778	21	19
40	54	**U of Houston**	4,003	44	3,225	2,722	2,117	2,423	1,816	24	17
		Total, first 40 institutions	$274,003	77%	$254,342	$231,661	$197,110	$176,927	$159,180[b]	8%	11%
41	42	**Washington State U**	3,934	64	3,844	1,356	692	558	583	2	46
42	46	**Rutgers U**	3,913	65	3,507	2,368	2,301	1,830	1,390	12	23
43	47	**U of California, Santa Barbara**	3,874	91	3,506	3,060	2,172	1,902	1,698	10	18
44	40	**Florida State U**	3,841	35	4,047	3,276	3,137	2,500	2,959	−5	5
45	86	**U of Cincinnati**	3,816	63	1,684	1,593	1,633	1,217	1,251	127	25
46	41	**Colorado State U**	3,713	88	3,867	2,775	2,688	2,478	2,479	−4	8
47	44	**Iowa State U**	3,684	43	3,709	2,998	2,239	1,903	1,462	−1	20
48	53	**State U of New York, Stony Brook**	3,669	73	3,333	3,481	3,084	2,607	2,783	10	6
49	59	**U of Washington**	3,655	63	2,971	2,964	2,340	2,162	2,276	23	10
50	73	**U of Oklahoma**	3,633	43	2,301	2,826	2,676	2,890	2,306	58	10
		Total, first 50 institutions	$311,735	75%	$287,111	$258,348	$220,072	$196,974	$178,367[b]	9%	12%
		NATIONAL TOTAL	$507,788	72%	$468,386	$422,087	$369,945	$334,663	$309,371[b]	8%	10%

Note: Data for institutional fiscal years. A number of institutions have developed or are in the process of developing new computer systems and methodologies that enable them to report more accurately the total cost of science and engineering research. Fiscal year 1987 comparisons with data reported in earlier years may be inappropriate in some areas. Data since 1984 were revised in 1987. **a** Estimated. **b** Total does not include spending at Rockefeller U. **Source:** National Science Foundation

SCHOOLS WITH MOST FEDERAL SUPPORT FOR CHEMICAL R&D: Big increase at Berkeley

Rank			1987	1986	1985	1984	1983	1982	Annual change	
1987	1986		($ thousands)						1986–87	1982–87
1	2	**U of California, Berkeley**	$ 11,160	$ 8,258	$ 9,892	$ 7,263	$ 7,467	$ 5,691	35%	14%
2	1	**Massachusetts Inst. of Technology**	10,656	12,909	12,424	11,055	8,374	9,096	−17	3
3	3	**California Inst. of Technology**	9,922	7,612	7,001	5,810	6,554	5,809	30	11
4	5	**U of California, Los Angeles**	9,414	7,516	6,719	6,389	5,047	4,978	25	14
5	7	**Harvard U**	8,309	6,748	6,557	6,307	5,224	4,174	23	15
6	4	**Stanford U**	7,918	7,524	7,097	6,120	5,968	5,893	5	6
7	9	**Cornell U**	6,753	5,934	6,293	5,775	4,766	5,437	14	4
8	16	**Columbia U, main division**	6,625	5,030	4,490	4,639	4,279	4,365	32	9
9	6	**U of Chicago**	6,499	6,769[a]	6,265[a]	5,116	3,998	3,716	−4	12
10	19	**U of Texas, Austin**	6,405	4,922	4,741	3,873	3,527	2,781	30	18
		Total, first 10 institutions	$ 83,661	$ 73,222	$ 71,479	$ 62,347	$ 55,204	$ 51,940	14%	10%
11	8	**U of Illinois, Urbana**	6,306	5,999	5,371	5,005	4,668	4,763	5	6
12	11	**Purdue U**	5,978	5,708	5,418	4,452	3,966	3,946	5	9
13	14	**U of Pennsylvania**	5,653	5,232	4,398	3,921	4,037	2,745	8	16
14	17	**U of Notre Dame**	5,158	4,998	5,097	4,416	3,867	3,866	3	6
15	21	**Johns Hopkins U**	5,116	4,903	4,155	3,783	3,604[a]	3,800	4	6
16	24	**Princeton U**	5,064	4,575	3,104	2,892	2,642	2,485	11	15
17	25	**U of Massachusetts, Amherst**	5,036	4,411	4,091	3,887	3,336	2,773	14	13
18	57	**Case Western Reserve U**	5,016	2,062	2,065	1,904	1,443	1,487	143	28
19	23	**Indiana U**	4,923	4,757	4,885	4,694	4,642	4,237	3	3
20	15	**Pennsylvania State U**	4,915	5,161	5,860	4,564	4,236	3,222	−5	9
		Total, first 20 institutions	$136,826	$121,028	$115,923	$101,865	$ 91,645	$ 85,264	13%	10%
21	12	**Yale U**	4,909	5,566[a]	5,095[a]	3,528	3,008	2,599	−12	14
22	13	**U of Wisconsin, Madison**	4,718	5,348	5,156	4,391	3,693	3,404	−12	7
23	29	**Northwestern U**	4,641	3,753	3,963	3,471	3,012	2,711	24	11
24	10	**U of California, San Diego**	4,599	5,918	4,053	3,780	3,490	3,506	−22	6
25	18	**Ohio State U**	4,517	4,931	3,846	2,904	2,870	2,355	−8	14
26	20	**U of Colorado**	4,402	4,911	5,430	3,358	2,695	2,755	−10	10
27	28	**U of Minnesota**	4,395	4,013	3,295	3,346	3,345	3,377	10	5
28	22	**U of Utah**	4,194	4,791	4,426	3,380	3,085	2,858	−12	8
29	30	**U of Maryland, College Park**	4,073	3,557	3,323	2,862	2,834	3,068	15	6
30	27	**U of Pittsburgh**	4,028	4,045	3,836	3,343	2,833	2,188	0	13
		Total, first 30 institutions	$181,302	$167,861	$158,346	$136,228	$122,510	$114,085	8%	10%
31	36	**Texas A&M U**	4,019	3,128	4,195	2,735	3,327	2,823	28	7
32	26	**U of Oregon, main campus**	3,579	4,345	3,959	3,524	2,686	2,530	−18	7
33	37	**U of California, Santa Barbara**	3,526	3,087	2,709	1,881	1,723	1,480	14	19
34	42	**U of Florida**	3,486	2,729	2,302	2,042	1,325	1,341	28	21
35	32	**U of California, Irvine**	3,386	3,394	3,035	2,096	1,725	1,593	0	16
36	41	**U of Virginia**	3,281	2,748	2,165	2,099	1,663	1,597	19	15
37	34	**U of Rochester**	3,275	3,336	2,861	3,490	2,800	2,774	−2	3
38	31	**Colorado State U**	3,273	3,403	2,434	2,426	2,055	2,230	−4	8
39	33	**Rockefeller U**	3,247	3,377	2,553	833	584	na	−4	—
40	38	**U of North Carolina, Chapel Hill**	3,153	2,929	2,885	2,699	2,381	2,218	8	7
		Total, first 40 institutions	$215,527	$200,337	$187,444	$160,053	$142,779	$132,671[b]	8%	10%
41	35	**U of South Carolina**	3,113	3,285	2,787	2,533	2,221	1,865	−5	11
42	40	**U of Southern California**	2,903	2,857	2,149	2,495	2,456	1,717	2	11
43	51	**State U of New York, Stony Brook**	2,669	2,210	2,343	2,069	1,809	1,901	21	7
44	46	**U of Michigan**	2,615	2,367	2,286	2,356	1,853	1,547	10	11
45	39	**Georgia Inst. of Technology**	2,565	2,914	2,051	2,227	2,032	1,800	−12	7
46	54	**Rutgers U**	2,525	2,123	2,055	2,129	1,740	1,333	19	14
47	45	**Washington State U**	2,501	2,414	1,211	682	525	554	4	35
48	47	**U of Arizona**	2,499	2,291	1,738	1,843	1,557	1,228	9	15
49	81	**U of Cincinnati**	2,403	1,235	1,022	1,099	748	1,082	95	17
50	58	**Brown U**	2,363	2,023	1,601	1,579	1,282	1,037	17	18
		Total, first 50 institutions	$241,683	$224,056	$206,687	$179,065	$159,002	$146,735[b]	8%	10%
		NATIONAL TOTAL	$365,480	$338,865	$312,325	$278,215	$247,652	$231,108[b]	8%	10%

Note: Data for institutional fiscal years. A number of institutions have developed or are in the process of developing new computer systems and methodologies that enable them to report more accurately the total cost of science and engineering research. Fiscal 1987 comparisons with data reported in earlier years may be inappropriate in some areas. Data since 1984 were revised in 1987. a Estimated. b Totals do not include Rockefeller U. **Source:** National Science Foundation

SCHOOLS SPENDING MOST ON CHEMICAL ENGINEERING R&D: MIT spends 8% of total

		Chemical engineering			All engineering		
Rank		Total spending ($ thousands)	Federal funds	% federal funds	Total spending ($ thousands)	Federal funds	% federal funds
1	**Massachusetts Inst. of Technology**	$ 11,147	$ 7,333	66%	$ 110,835	$ 80,331	72%
2	**U of Minnesota**	6,283	3,614	58	23,161	8,280	36
3	**U of Texas, Austin**	4,291	1,728	40	44,682	21,489	48
4	**New Mexico Inst. of Mining & Tech.**	4,127	407	10	20,335	7,451	37
5	**John Hopkins U**	3,571[a]	3,550[a]	99	172,790	170,869	99
6	**U of Wisconsin, Madison**	3,518	2,123	60	30,076	18,810	63
7	**North Carolina State U, Raleigh**	3,348	1,044	31	24,068	8,132	34
8	**U of Maryland, College Park**	3,280	1,037	32	34,532	15,881	46
9	**Brigham Young U**	3,277	2,067	63	5,242	3,151	60
10	**Texas A&M U**	2,909	234	8	33,385	8,467	25
	Total, first 10 institutions	**$ 45,751**	**$23,137**	**51%**	**$ 499,106**	**$ 342,861**	**69%**
11	**Stanford U**	2,907	2,605	90	68,008	56,610	83
12	**Lehigh U**	2,508	821	33	16,995	5,866	35
13	**U of Delaware**	2,304	987	43	11,699	4,954	42
14	**U of Pennsylvania**	2,194	1,655	75	8,745	4,808	55
15	**Georgia Inst. of Technology**	2,162	1,134	52	84,329	44,239	52
16	**U of Michigan**	2,131	1,532	72	35,850	18,566	52
17	**Columbia U, main division**	2,122	227	11	12,806	9,743	76
18	**Case Western Reserve U**	2,115	1,495	71	14,104	10,072	71
19	**Louisiana State U**	1,920	694	36	8,480	2,129	25
20	**U of Washington**	1,919	1,022	53	19,101	10,453	55
	Total, first 20 institutions	**$ 68,033**	**$35,309**	**52%**	**$ 779,223**	**$ 510,301**	**65%**
21	**Pennsylvania State U**	1,907	687	36	68,326	45,736	67
22	**Cornell U**	1,886	1,064	56	35,128	21,592	61
23	**Princeton U**	1,801	959	53	15,084	9,873	65
24	**California Inst. of Technology**	1,776	1,525	86	14,436	12,357	86
25	**Purdue U**	1,735	1,104	64	30,371	19,104	63
26	**U of California, Berkeley**	1,719	1,185	69	39,888	24,446	61
27	**U of Pittsburgh**	1,682	1,172	70	5,908	3,185	54
28	**U of Houston**	1,556	578	37	7,359	2,609	35
29	**Auburn U**	1,493	542	36	15,290	7,166	47
30	**Syracuse U**	1,473	648	44	4,985	2,147	43
	Total, first 30 institutions	**$ 85,061**	**$44,773**	**53%**	**$1,015,998**	**$ 658,516**	**65%**
	NATIONAL TOTAL	**$140,438**	**$69,880**	**50%**	**$1,888,718**	**$1,111,740**	**59%**

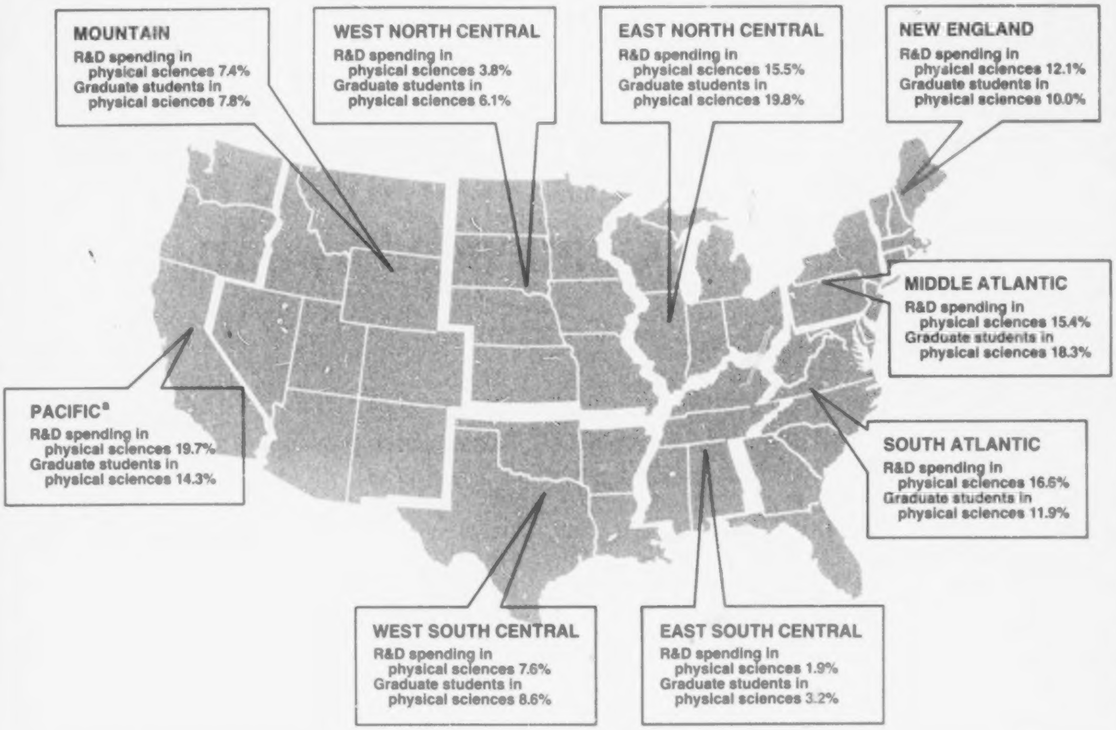
Note: Data for fiscal 1987. a Estimated. **Source:** National Science Foundation

FOREIGN GRADUATE STUDENTS: Their fraction of total is growing in all fields

	1987		1986		1985		1984		1983		1982		Annual change	
	Thousands	% of total	Thousands	% of total	Thousands	% of total	Thousands	% of total	Thousands	% of total	Thousands	% of total	1986–87	1982–87
All sciences	**48.8**	**24%**	**46.3**	**23%**	**42.5**	**22%**	**38.6**	**20%**	**37.5**	**20%**	**34.5**	**18%**	**5%**	**7%**
Psychology and social sciences	13.2	18	12.7	18	12.1	18	11.2	16	11.2	16	10.8	15	4	4
Life sciences	13.2	19	12.2	18	11.0	17	10.2	15	10.0	15	9.3	14	9	7
Biochemistry	1.2	26	1.1	23	1.0	22	0.8	20	0.8	19	0.7	17	9	13
Mathematical and computer sciences	10.9	42	10.4	41	9.5	41	8.3	40	7.6	39	6.5	36	5	11
Physical sciences	9.6	35	9.3	34	8.3	32	7.4	30	7.0	29	6.3	27	4	9
Chemistry	4.7	30	4.4	28	4.0	26	3.5	24	3.4	23	3.1	22	8	9
Physics	4.7	43	4.7	44	4.1	41	3.8	38	3.5	38	3.1	35	0	9
Environmental sciences	1.9	18	1.8	16	1.6	15	1.6	14	1.7	14	1.6	15	4	3
Engineering	**27.3**	**45**	**26.6**	**44**	**23.7**	**43**	**22.8**	**42**	**22.4**	**42**	**20.8**	**43**	**3**	**6**
Chemical	2.3	41	2.2	39	2.2	40	2.1	37	2.2	38	2.3	42	7	0
Metallurgical and materials	1.5	45	1.5	45	1.3	42	1.2	42	1.2	43	1.2	48	3	5
TOTAL	**76.2**	**29%**	**73.0**	**28**	**66.2**	**26**	**61.4**	**25**	**59.9**	**25**	**55.3**	**23**	**4%**	**7%**
ANNUAL CHANGE	**4.4%**		**10.2%**		**7.7%**		**2.5%**		**8.4%**		**5.1%**			

Note: Data are for full-time graduate students at Ph.D.-granting institutions only. **Source:** National Science Foundation

Three fifths of R&D funding and graduate students are east of Mississippi River



MOUNTAIN
R&D spending in physical sciences 7.4%
Graduate students in physical sciences 7.8%

WEST NORTH CENTRAL
R&D spending in physical sciences 3.8%
Graduate students in physical sciences 6.1%

EAST NORTH CENTRAL
R&D spending in physical sciences 15.5%
Graduate students in physical sciences 19.8%

NEW ENGLAND
R&D spending in physical sciences 12.1%
Graduate students in physical sciences 10.0%

MIDDLE ATLANTIC
R&D spending in physical sciences 15.4%
Graduate students in physical sciences 18.3%

PACIFIC[a]
R&D spending in physical sciences 19.7%
Graduate students in physical sciences 14.3%

SOUTH ATLANTIC
R&D spending in physical sciences 16.6%
Graduate students in physical sciences 11.9%

WEST SOUTH CENTRAL
R&D spending in physical sciences 7.6%
Graduate students in physical sciences 8.6%

EAST SOUTH CENTRAL
R&D spending in physical sciences 1.9%
Graduate students in physical sciences 3.2%

Key to map: Using the Middle Atlantic states as an example, 15.4% of all R&D expenditures in the physical sciences and 18.3% of all graduate students in the physical sciences at Ph.D.-granting universities and colleges are in this area.

Note: Data based on $1.35 million of R&D expenditures and 31,000 graduate students enrolled in the physical sciences at Ph.D-granting colleges and universities during the 1987 fiscal year. a Includes Alaska, Hawaii, and outlying areas. **Source:** National Science Foundation

GRADUATE SCIENCE STUDENTS: Little change in 1987 for either science or engineering

												Annual change	
Thousands	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1986–87	1977–87
All sciences	290.7	286.5	280.6	274.8	271.8	268.6	265.6	263.5	253.4	245.5	242.2	1%	2%
Psychology and social sciences	108.1	105.3	104.6	104.2	105.5	107.3	108.7	109.7	105.8	101.2	100.6	3	1
Life sciences	96.6	95.8	93.3	92.4	91.2	90.7	90.9	90.7	87.5	85.9	83.3	1	1
Biochemistry	4.8	4.9	4.7	4.5	4.2	4.1	4.0	4.0	3.9	4.0	3.8	−2	2
Mathematical and computer sciences	41.6	40.9	39.1	35.4	33.2	30.3	27.1	25.0	22.7	21.5	21.1	2	7
Physical sciences	31.0	30.5	29.3	28.4	27.7	26.5	25.8	25.4	24.9	24.7	24.8	1	2
Chemistry	17.6	17.6	17.2	16.6	16.5	15.8	15.2	15.1	14.9	14.8	14.6	0	2
Physics	12.3	12.0	11.3	11.0	10.5	10.0	9.9	9.6	9.3	9.2	9.5	3	3
Environmental sciences	13.5	14.1	14.3	14.3	14.3	13.8	13.1	12.8	12.6	12.2	12.3	−4	1
Engineering	98.0	96.9	91.4	88.3	86.4	78.2	74.4	70.1	67.2	64.3	64.4	1	4
Chemical	7.0	6.9	7.0	7.2	7.4	6.9	6.3	5.9	5.4	5.2	5.1	2	3
Metallurgical and materials	4.2	4.0	3.8	3.6	3.3	3.0	3.0	2.8	2.7	2.5	2.5	3	5
Petroleum	0.8	0.7	0.8	0.7	0.7	0.6	0.5	0.5	0.4	0.4	0.4	13	7
TOTAL	388.7	383.5	372.0	363.1	358.3	346.8	340.0	333.7	320.6	309.8	306.6	1	2
ANNUAL CHANGE	1%	3%	2%	1%	3%	2%	2%	4%	3%	1%	3%		

Note: Data for Ph.D.-granting institutions only. **Source:** National Science Foundation

5 R&D International

U.S. Dominance of Worldwide R&D Increasingly Challenged by Japan

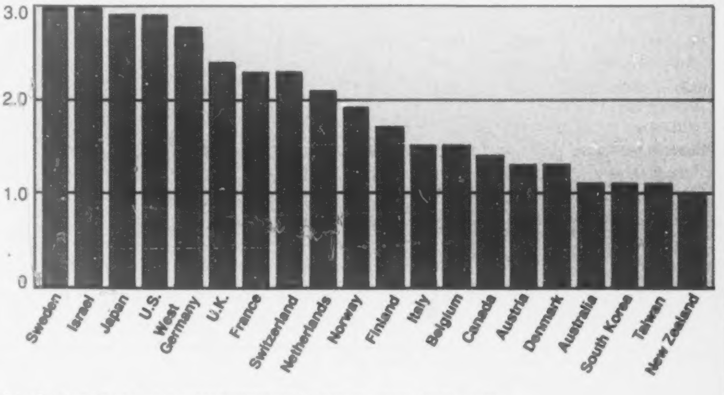
WORLDWIDE R&D SCIENTISTS AND ENGINEERS: Researchers growing as share of work force

Thousands	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	Annual change 1986–87	Annual change 1977–87
U.S.	806	791	773	746	723	703	683	651	615	587	561	2%	4%
Japan	418	406	381	370	342	330	318	303	282	273	272	3	4
West Germany	152[a]	147[a]	144	137[a]	131	128[a]	125	121[a]	117	113[a]	111	3	3
France	108[a]	105[a]	102	98	93	90	86	75	73	71	68	3	5
U.K.	na	99	98	96[a]	94	na	96	na	na	88	na	1[b]	—
Per 10,000 in labor force													
U.S.	na	66.2	65.9	64.7	63.8	62.8	61.9	60.0	57.7	56.5	55.7	—	—
Japan	na	67.4	63.9	62.4	58.1	57.1	55.6	53.6	50.4	49.4	49.9	—	—
West Germany	na	52.3[a]	51.6	49.6[a]	47.4	46.4[a]	45.5	44.3[a]	43.4	42.7[a]	41.8	—	—
France	na	43.8[a]	42.8	41.1	39.1	37.9	36.3	32.1	31.4	30.7	29.7	—	—
U.K.	na	35.5	35.5	35.5[a]	35.4	na	35.8	na	na	33.3	na	—	—

Note: Table represents all scientists and engineers engaged in R&D on a full-time equivalent basis except Japan, whose data include persons primarily employed in R&D in the natural sciences and engineering, and all higher education natural science and engineering faculty. The U.K. data include only the government and industry sectors. The figures for West Germany increased in 1979 partially because of increased coverage of small and medium-sized enterprises not surveyed in 1977. The data for France increased in 1981 in part due to a reevaluation of university research efforts. **na** = not available. **a** Estimated. **b** Annual change is for 1985–86. **Source:** National Science Foundation

Sweden, Israel spend biggest part of GNP on R&D

Total R&D as % of gross national product



Note: Data are for most current year available. **a** C&EN estimate based on NSF data.
Source: National Science Foundation

WORLDWIDE R&D EXPENDITURES: 20 countries spend more than $1 billion on R&D annually

	$ Millions, constant 1982	% of GNP		$ Millions, constant 1982	% of GNP		$ Millions, constant 1982	% of GNP
U.S. (1987)	$110,100	2.9%	**Netherlands** (1985)	3,100	2.1	**South Korea** (1983)	1308	1.1
Japan (1987)	39,118	2.9	**Switzerland** (1983)	2,131	2.3	**Finland** (1987)	1236	1.7
West Germany (1987)	19,371	2.8	**Spain** (1984)	1,762	0.5	**Argentina** (1981)	1087	0.4
U.K. (1986)	13,765	2.4	**Australia** (1985)	1,718	1.1	**Norway** (1987)	1007	1.9
France (1987)	13,728	2.3	**India** (1984)	$1482	0.9%	**Denmark** (1985)	707	1.3
Italy (1987)	7,394	1.5	**Brazil** (1985)	1448	0.7	**Israel** (1983)	637	3.0
Canada (1986)	4,877	1.4	**Belgium** (1983)	1442	1.5	**Taiwan** (1985)	505	1.1
Sweden (1987)	3,967	3.0	**Austria** (1987)	1310	1.3	**New Zealand** (1985)	204	1.0

Note: Data are for the most current year available (in parentheses). Countries differ in statistical collection capabilities and definitions. In addition, some R&D/gross national product percentages are R&D/gross domestic product. Foreign currency conversions to U.S. dollars were calculated with Organization for Economic Cooperation & Development purchasing power parities or using International Monetary Fund average-for-period par/market exchange rates. **Source:** National Science Foundation

TOTAL AND NONDEFENSE R&D: U.S. lead shrinks when only nondefense R&D is considered

												Annual change	
$ Billions, constant 1982	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1986–87	1977–87
TOTAL R&D													
U.S.[a]	$110.1	$106.9	$103.8	$95.1	$86.2	$80.4	$76.5	$73.0	$69.9	$66.7	$63.6	2%	5%
Japan	39.1	36.6	36.1	32.4	29.9	27.4	25.5	23.1	21.0	19.1	18.0	7	8
West Germany	19.4	18.6	18.5	16.9	16.4	16.3	15.9	15.3	15.0	13.3	12.4	4	5
U.K.	na	13.8	12.9	na	11.9	na	12.2	na	na	11.1	na	7[b]	—
France	13.7	13.6	13.1	12.6	11.9	11.5	10.8	9.8	9.4	8.9	8.6	1	5
NONDEFENSE R&D													
U.S.[a]	$ 72.7	$ 71.6	$ 70.6	$66.6	$62.1	$59.5	$58.1	$56.9	$53.8	$50.0	$47.0	1%	4%
Japan	38.8	36.3	35.8	32.2	29.7	27.2	25.4	23.0	20.8	18.9	17.9	7	8
West Germany	18.4	17.7	17.6	16.2	15.7	15.6	15.2	14.5	14.2	12.5	11.6	4	5
U.K.	na	10.3	9.2	na	8.4	na	8.7	na	na	8.0	na	12[b]	—
France	10.9	10.9	10.5	9.9	9.4	9.0	8.1	7.6	7.4	7.1	7.0	0	5

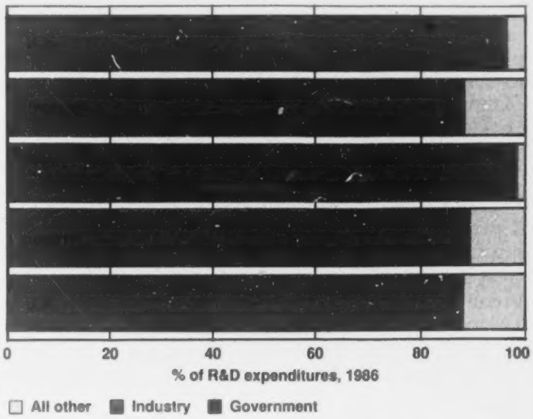
Note: Foreign currency conversions to U.S. dollars are calculated based on Organization for Economic Cooperation & Development purchasing power parity exchange rates. **a** C&EN estimates based on NSF data. **b** Annual change is for 1985–86. **na** = not available. **Source:** National Science Foundation

ORIGIN OF CHEMICAL LITERATURE: Japan's share rises as Soviet Union's declines

% of total[a]	1988	1984	1980	1976	1972
U.S.	27.4%	27.1%	26.2%	25.6%	28.0%
U.S.S.R.	13.0	16.8	19.0	24.1	24.0
Japan	11.5	10.4	10.4	7.8	7.9
West Germany	6.3	6.0	5.8	5.9	5.7
U.K.	5.6	5.6	5.9	6.4	6.4
France	4.3	4.0	4.2	4.2	4.4
China	3.5	2.3	0.7	0.1	0.0
Canada	3.1	2.8	2.6	2.7	2.8
India	3.1	3.2	3.4	2.8	2.5
Italy	2.4	2.5	2.4	2.0	1.9
Poland	1.7	1.7	2.1	2.0	2.0
Netherlands	1.5	1.4	1.2	1.1	1.0
Spain	1.4	1.0	0.7	0.5	0.4
Australia	1.3	1.3	1.2	1.2	1.2
East Germany	1.2	1.2	1.2	1.2	0.5
Sweden	1.2	1.2	1.1	1.1	1.1
Czechoslovakia	1.1	1.2	1.4	1.5	1.7
Switzerland	1.1	1.0	1.0	1.1	1.0
All others	9.3	9.3	9.5	8.7	7.5
TOTAL PAPERS (THOUSANDS)	389.7	380.7	407.3	318.0	280.1

a Source of journal literature abstracted in *Chemical Abstracts* based on authors address. **Source:** Chemical Abstracts Service

Industry's share of R&D outlays is greatest in Japan



a Estimated. **b** Data are for 1987. **Source:** National Science Foundation

ACS-PRF Grants Approved

Acting on recommendations from the May meeting of the Petroleum Research Fund Advisory Board, the ACS Board of Directors approved 155 new or continuing ACS-PRF grants totaling $4,106,471. The recommended grants were selected from 467 proposals and are the last projects to be funded in 1989. Total ACS-PRF grant commitments in 1989 total $12,683,447. ACS-PRF grants are funded by income from a trust established in 1944 by seven major oil companies. No ACS member dues income is used for PRF grants or administrative expenses.

The PRF Advisory Board has begun a review of the adequacy and appropriateness of current PRF grant programs. Scientists wishing to comment on any aspect of PRF operations, or to suggest possible new grant programs, are invited to communicate with the program administrator, Joseph E. Rogers Jr., at the address below.

Proposals for projects to commence in 1990 are invited for all ACS-PRF research grant programs. Information and application forms may be obtained from the Petroleum Research Fund, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036, or by calling (202) 872-4481.

ACS-PRF Grants for Fundamental Research in the Petroleum Field (Type AC)

Brent Kopliltz, Tulane U. Laser-Induced Photochemistry of Metalorganic Compounds Relevant to the Fabrication of III-IV Semiconductor Materials. $40,000

Frederick G. Bordwell, Northwestern U. Structural Effects on Homolytic Bond Dissociation Energies of Weak Acids. $40,000

Bruce H. Lipshutz, U of California, Santa Barbara. Development and Applications of Novel Organocopper-Mediated Transmetalation Processes. $40,000

Ryong-Joon Roe, U of Cincinnati. Solubility of Homopolymer in Block Copolymer. $40,000

Jeffrey L. Petersen, West Virginia U. Systematic Reactivity Studies of Highly Electrophilic Sila-Metallacyclobutane and Cationic Metallocene Alkyl Complexes. $40,000

M. David Curtis, U of Michigan. Chemistry of Monocyclopentadienyl Complexes of Niobium and Tantalum. $40,000

Cheng-cher Huang, U of Minnesota. Physical Properties of Chiral Liquid Crystal Compounds. $40,000

James M. Lisy, U of Illinois, Urbana-Champaign. Vibrational Spectroscopy of Metal Ion-Solvent Clusters. $40,000

Timothy P. Lodge, U of Minnesota. Diffusion of Linear and Star Polymers in Random Media. $40,000

John E. Ellis, U of Minnesota. Studies on the Hexacarbonylmetallates(2-) of Titanium, Zirconium, and Hafnium and Related Materials. $20,000

Darrel S. Cowan, U of Washington. Structural Evolution and Kinematic History of the Badwater Turtleneck Detachment Fault, Death Valley, California. $40,000

Emanuel Mazor, Weizmann Institute of Science. ^{4}He and ^{40}Ar Dating of Natural Gas and Oil. $20,000

T. Darrah Thomas, Oregon State U. Electron Spectroscopic and Theoretical Investigations of Small Molecules. $40,000

Richard C. Larock, Iowa State U. Organic Synthesis via Palladium Migration. $40,000

Elizabeth L. Miller, Stanford U. Paleozoic and Mesozoic Geology and Geochronology of the Pine Forest Range, Northwest Nevada. $39,523

Jayanth R. Banavar, Pennsylvania State U. Diffusion in Porous Media. $40,000

Herbert F. Wang, U of Wisconsin, Madison. Flexural and Thermal Modeling of the Midcontinent Rift. $40,000

Michael W. W. Adams, U of Georgia. The Metabolism of Gases by Extremely Thermophilic Bacteria. $40,000

William D. Johns, U of Missouri, Columbia. Experimental High-Temperature-Pressure Compaction Diagenesis of Shale. $40,000

Rudiger Dieckmann, Cornell U. Problems in the Application of Electrochemical Devices for Coulometric Titrations with Doped Zirconia as Electrolyte. $40,000

George W. Luther III, U of Delaware. Investigation of the Reactivity of Pyrite with Inorganic and Organic Compounds. $40,000

Martyn Poliakoff, U of Nottingham. Time-Resolved Infrared Studies in Supercritical Xenon. $40,000

Jeffrey L. Bada, U of California, San Diego. Organic Geochemical Applications of Two-Step Laser Mass Spectrometry. $40,000

Thomas G. Richmond, U of Utah. Carbon-Heteroatom Bond Activation. $40,000

Gautam Mitra, U of Rochester. Tectonothermal Evolution of the Southern Anthracite Region, Pennsylvania: Implications for the Development of Blind Thrust Systems. $39,950

Stephen L. Buchwald, Massachusetts Institute of Technology. Early Transition-Metal Complexes of Multiply Unsaturated Organic Molecules. $40,000

Robert W. Murray, U of Missouri, St. Louis. Dioxirane Chemistry. $40,000

Stephen J. Guggenheim, U of Illinois, Chicago. The Thermal Stability of Trioctahedral Layer Silicates. $40,000

Bernard D. Coleman, Rutgers U. Rheology of Cold Drawing of Polymeric Materials. $40,000

Carlton E. Brett, U of Rochester. Dynamic Stratigraphy of the Wenlockian Series (Upper Silurian) in the Northern Appalachian Basin. $40,000

Frank A. Podosek, Washington U. Study of Natural Isotopic Fractionation Effects in Iron. $40,000

Dennis P. Curran, U of Pittsburgh. Sequential Carbon-Carbon Bond Formation: the Combination of Radical and Ionic Reactions. $40,000

John C. Wright, U of Wisconsin, Madison. Geochemical Applications of Site-Selective Laser Spectroscopy. $40,000

William Weltner Jr., U of Florida. ESR, ENDOR, and Far-IR Spectroscopy of Clusters. $40,000

Jacqueline Krim, Northeastern U. Investigation of Self-Affine Surface Fractals through Adsorption Isotherms. $40,000

Mark O. Robbins, Johns Hopkins U. Dynamics of Fluid Interfaces in Porous Media: Viscous Fingering and the Depinning Transition. $40,000

Harry M. Walborsky, Florida State U. Stereochemistry of Capto-Dative Reactions. $40,000

John F. Garst, U of Georgia. Mechanism of the Barbier Synthesis. $40,000

George A. McMechan, U of Texas, Dallas. Numerical Simulation of the Elastic Seismic Response of Hydrocarbon Reservoirs Using Biot Theory. $40,000

Stephen Garoff, Carnegie Mellon U. Origins of Dynamic Wettability and Contact Angle Hysteresis. $40,000

Jeremy N. S. Evans, Washington State U. Rapid Reactions by Solid-State NMR. $40,000

Jorge V. Jose, Northeastern U. Theoretical Studies of Nonlinear and Dynamic Effects in Disordered Media. $40,000

R. Paul Philip, U of Oklahoma. The Use of Tandem Mass Spectrometry (MS/MS) in the Search for Novel High-Molecular-Weight Biomarkers. $40,000

Glen A. Russell, Iowa State U. Chain Reactions Involving Electron Transfer. $40,000

Thomas Bein, U of New Mexico. Encapsulation of Heterobimetallic Species in Large-Pore Zeolites. $40,000

Anthony J. McHugh, U of Illinois, Urbana-Champaign. Flow-Induced Structure Formation and Phase Separation in Polymer Solutions. $38,250

Thomas F. Keyes, Boston U. Normal Mode Analysis of Liquid State Dynamics. $40,000

Richard D. Ernst, U of Utah. Synthesis, Characterization, and Reaction Chemistry of Transition-Metal Polyhydride Compounds. $40,000

Tadeusz W. Zerda, Texas Christian U. Hydrolysis Reaction in Sol-Gel Processes. $40,000

Kirk S. Schanze, U of Florida. Ligand-to-Ligand Charge Transfer States of Re(I) Complexes. $40,000

William C. Kelly, U of Michigan. Geologic and Thermochemical History of the White Pine District, Keweenaw Rift, Northern Michigan. $40,000

John R. Bowman, U of Utah. Stable Isotope and Hydrothermal Alteration Studies of Fluid Rock Interaction in Basin and Range Normal Faults. $40,000

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NEWS

High-Performance Plastics

Electronic applications drive growth in demand Page 21

CHEMICAL & ENGINEERING
NEWS
SEPTEMBER 4, 1989

Volume 67, Number 36
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News of the Week

- **West Germany's Hoechst discloses relatively weak first-half gains, but positive performances by other European giants allay analysts' fears of an economic downswing for European chemical industry.** Page 4
- **Privately owned rocket makes landmark flight to launch payload into orbit, heralding emergence of U.S. commercial launch industry.** Page 4
- **Voyager 2 last week completed what mission scientists are calling a nearly flawless encounter with the planet Neptune.** Page 5
- **EPA orders 90% cut of industrial benzene emissions over the next several years, but cost to chemical producers will likely be negligible.** Page 5
- **Washington-headquartered environmentalist group "Renew America" releases report calling for action on the environmental problems of the rural U.S.** Page 6

Cover: General Electric worker prepares electronic components with process that uses chemical bond for adhesion between metal and plastic substrates

Letters 2

Concentrates

Business 9
Government 13
Science/Technology 17

The Departments

Meetings 61
Newscripts 84

Business

Chemical industry productivity declined in the second quarter, after slowing in growth for some months, and unit labor costs continued to increase. **Page 11**

Government

Pentagon won't get any new funds for producing chemical weapons this coming fiscal year if House actions prevail in conference committee with Senate; industry support for National Science Foundation programs is growing, is now a significant factor in their funding. **Page 14**

Science Policy

Planning an R&D strategy for Europe 1992 will be challenging, complex for the 12 EC nations, according to recently released report. **Page 16**

Science/Technology

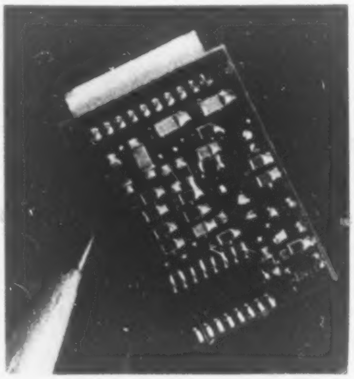
IUPAC ponders restructuring, efforts to publicize role of chemistry and increase visibility within the chemical community during its recent 35th general assembly. **Page 18**

Books

Arthur Kornberg's autobiography, "For the Love of Enzymes," presents personal development and scientific discoveries, expresses convictions on society and education. **Page 54**

ACS News

R&D executives rate ACS rather highly, a survey by the society's Corporation Associates shows; drug testing in the workplace, pollution prevention are topics of two recent ACS policy statements. **Page 60**



Product Report

Electronic, auto under-the-hood uses spur growth of high-performance plastics in markets that have been dominated by ceramics and specialty metals. Page 21

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LETTERS

Methyl chloroform concern

SIR: In an article about stratospheric ozone (C&EN, June 26, page 33), you devoted a significant amount of space to describing the Environmental Protection Agency's presentation at an international conference last May. You accurately point out that some EPA staff members are concerned about their estimate of the impact of methyl chloroform on stratospheric ozone by the middle of the next century. What was not included in your description were the erroneous assumptions underlying this estimate.

The current concern about methyl chloroform is predicated on the belief that, left unchecked, production of the chemical will increase fourfold by the year 2050. Such growth of a specialty chemical that is already reaching the peak of its growth curve is unprecedented and extremely unlikely.

Methyl chloroform is not a substitute for most of the uses of the chlorofluorocarbons subject to the Montreal protocol, so such substitution will not be the cause of any significant growth. The EPA estimate of growth is based simply on that agency's prediction of a rise in gross national product. This simplistic approach ignores the following four factors that will work together to limit (or eliminate) growth in methyl chloroform: In addition to methyl chloroform there are other substitutes for CFC-113 (the only fully halogenated CFC for which methyl chloroform has any substitution potential); there is a distinct rise in the recycling and incineration of methyl chloroform; conservation and environmental stewardship programs initiated by the methyl chloroform producers will curtail emissions of the chemical by the many industries that depend on it; and EPA announcement of concern and efforts to discourage use of methyl chloroform in place of CFC-113 will have a chilling effect on the market.

Even with the erroneous assumptions, EPA's charts clearly indicate that little benefit would be gained from either a reduction in or phase-out of the chemical, compared with continued use at today's levels. The most striking aspect of EPA's charts is that the most important factor in reducing depletion is eliminating use of CFCs. This can only be done, with current technology, by using methyl chloroform and other replacements that, although they may have an ozone-depleting potential, will reduce depletion eight- to 12-fold compared with the CFCs they replace. In addition, EPA's charts recognize the urgent need to get all the nations of the world to sign the Montreal protocol. There is little doubt that reopening the protocol for the addition of chemicals would decrease our chances of obtaining more complete worldwide compliance. Such an action might be counterproductive, in light of the likelihood that methyl chloroform will not grow significantly during the coming years.

Paul A. Cammer
President, Halogenated Solvents
Industry Alliance
Washington, D.C.

Creating dearth of chemists

SIR: Industry has been crying wolf for a number of years about the impending dearth of chemists. ACS has tried to respond to the need by the use of creative programs to induce precollege students to seek careers in chemistry. However, despite all of these efforts, the number of graduating chemists has remained essentially static over the past decade in the face of an expanding economy and increasing college enrollments.

The article "Chemical Firms Growing Wary of Lawsuits in Terminating Employees" (C&EN, May 22, page 23) has indicated one of the problems associated with efforts to increase the number of would-be chemists. This article shows clearly that many chemical companies have been terminating their older chemists with little regard for the past and present achievements of these same chemists and at the same time desperately recruiting younger chemists. I testified about this problem before the Senate Subcommittee on Labor in May 1988 at a hearing devoted to the issue of waivers. The stories about the arbitrary use of waivers to force older individuals out of not only retrenching but also expanding companies were nightmarish.

What sort of example has been set for potential young chemists by this arbitrary behavior of some of the members of the chemical industry? Older terminated chemists certainly would not recommend chemistry as a profession to any precollege or college students making a choice as to their future career. Young industrial chemists are not blind to what is occurring to their older colleagues and are questioning their career choice. Any dearth of chemists in the future can rightly be partially attributed to the callous treatment of older chemists by too large a number of chemical companies. I suggest that chemical com-

Chemical Industry Productivity Falls in Second Quarter

Decline, a sign of a slowing chemical economy, is result of flat output and increased workhours, is coupled with rise in unit labor costs

Productivity growth in the chemical industry has been slowing for some months and in the second quarter it stopped growing at all and actually dropped, based on calculations using recently released government figures. This is the first time in two and a half years that a quarter-to-quarter change in productivity has been lower than zero.

The pattern of productivity increases shows the signs characteristic of the latter stages of a business expansion—year-to-year growth slowing for each quarter and quarter-to-quarter changes fluctuating between growth and shrinkage. This is brought about essentially by production growth not keeping pace with employment. Productivity is figured by dividing indexes for production by indexes for aggregate weekly hours of production, which are a function of total production employment and the number of hours worked. This gives an index for unit output per hour of labor.

For the second quarter of 1989, production of chemicals and allied products showed no change from the first quarter and the index of hours increased 1.0% to 101.1 (all indexes are on a 1977 = 100 basis). The result was that productivity for the quarter declined 0.9% from the first quarter to 157.2. For the first quarter, productivity was up a scant 0.1% from fourth-quarter 1988.

On an annual basis, second-quarter productivity improved 2.6% from the same period in 1988 as output rose 8.2% and workhours climbed 3.6%. Productivity in the first quarter was up 5.4% on a year-to-year comparison. Thus second-quarter annual growth has slowed considerably from that in the first quarter.

Chemicals in quarterly comparisons did not do so well as all manufacturing. Productivity in this sector of the economy is still growing, rising 0.8% in the second quarter from the first to an index of 153.2. First-quarter productivity for all manufacturing was up 0.4% from the fourth quarter. On an annual basis, second-quarter productivity for all manufacturing was up 3.4% from a year earlier. First-quarter productivity was up 3.8% from the first quarter of 1988.

While productivity for the chemical industry was falling in the second quarter, the other important measure—unit labor costs—was rising, also a sign of a slowing chemical economy and one that translates to a negative impact on companies' financial results. Unit labor costs are labor costs per unit of output, calculated by dividing indexes for wages by the indexes for output per workhour or productivity.

In the second quarter, unit labor costs for chemicals climbed 1.7% from the first quarter to an index of 128.5 as productivity fell 0.9% and wages increased 0.8%. This is the third straight rise for unit labor costs on a quarterly basis, although in both the first quarter of this year and in fourth-quarter 1988, this index rose a much more moderate 0.2%.

On an annual basis, unit labor costs for chemicals rose 0.6% in the second quarter from second-quarter 1988. This is the first annual increase since the third quarter of 1987. In the first quarter, unit labor costs declined 2.5% from the first quarter of 1988.

Again, all manufacturing is performing somewhat better than chemicals. Unit labor costs in this sector in the second quarter fell 0.4% from the first quarter, and were down 0.7% from the second quarter in 1988. However, in the first quarter,

Productivity for all manufacturing is still growing

	Quarters, 1989		Quarters, 1988				Quarters, 1987			
Indexes, 1977 = 100	2nd	1st	4th	3rd	2nd	1st	4th	3rd	2nd	1st
CHEMICALS & ALLIED PRODUCTS										
Production	158.9	158.9	157.4	154.5	149.5	146.7	144.2	141.8	138.2	135.8
Workhours	101.1	100.1	99.3	98.5	97.6	97.5	96.8	95.4	93.6	93.3
Productivity	157.2	158.7	158.5	156.9	153.2	150.5	149.0	148.6	147.6	145.6
Hourly production wages	202.0	200.4	199.9	197.4	195.6	195.1	195.2	193.2	191.3	189.8
Unit labor costs	128.5	126.3	126.1	125.8	127.7	129.6	131.0	130.0	129.6	130.4
ALL MANUFACTURING										
Production	148.0	147.0	145.8	144.0	141.6	139.5	137.9	135.7	133.2	131.6
Workhours	96.6	96.7	96.3	95.7	95.6	95.2	95.0	93.5	92.6	92.5
Productivity	153.2	152.0	151.4	150.5	148.1	146.5	145.2	145.1	143.8	142.3
Hourly production wages	183.5	182.8	181.4	179.2	178.6	177.2	176.2	174.4	173.8	173.5
Unit labor costs	119.8	120.3	119.8	119.1	120.6	121.0	121.3	120.2	120.9	121.9

Sources: Federal Reserve Board, Department of Labor

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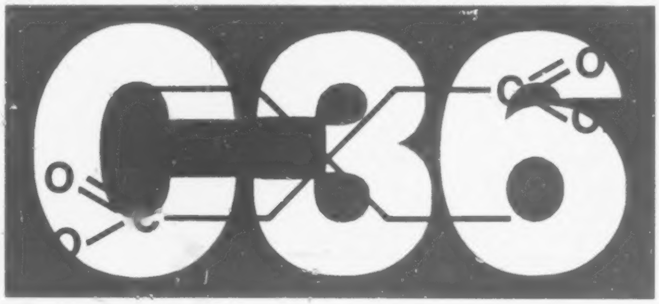

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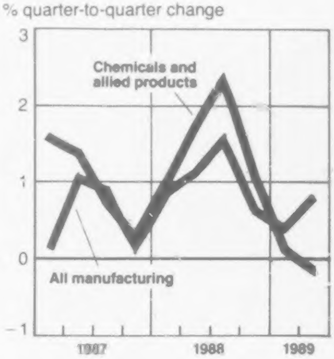
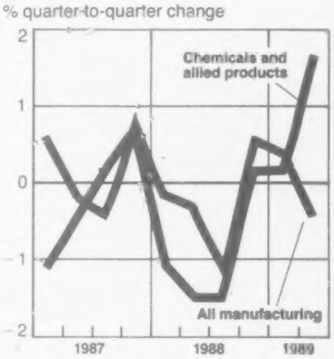
CIRCLE 54 ON READER SERVICE CARD

Chemical productivity declines...



...and unit labor costs continue to rise



Note: Productivity is output per workhour, calculated by dividing indexes for production by indexes for workhours of production employees. Unit labor costs are labor costs per unit of output, calculated by dividing indexes for wages by indexes for output per workhour.
Sources: Federal Reserve Board, Department of Labor

unit labor costs increased 0.4% from the previous quarter, although they were down 0.6% on an annual basis.

For the first six months of 1989, chemical productivity was up only 0.2% from the second half of 1988, but up 4.0% from the first six months last year. Productivity for all manufacturing increased 1.1% from the second half of 1988 and 3.2% from the first six months.

Unit labor costs for chemicals in the first half were up 1.1% from the second half of 1988, but down 1.0% from the first half. For all manufacturing, first-half 1989 unit labor costs rose 0.5% from the second six months of 1988, but declined 0.6% from first-half 1988.

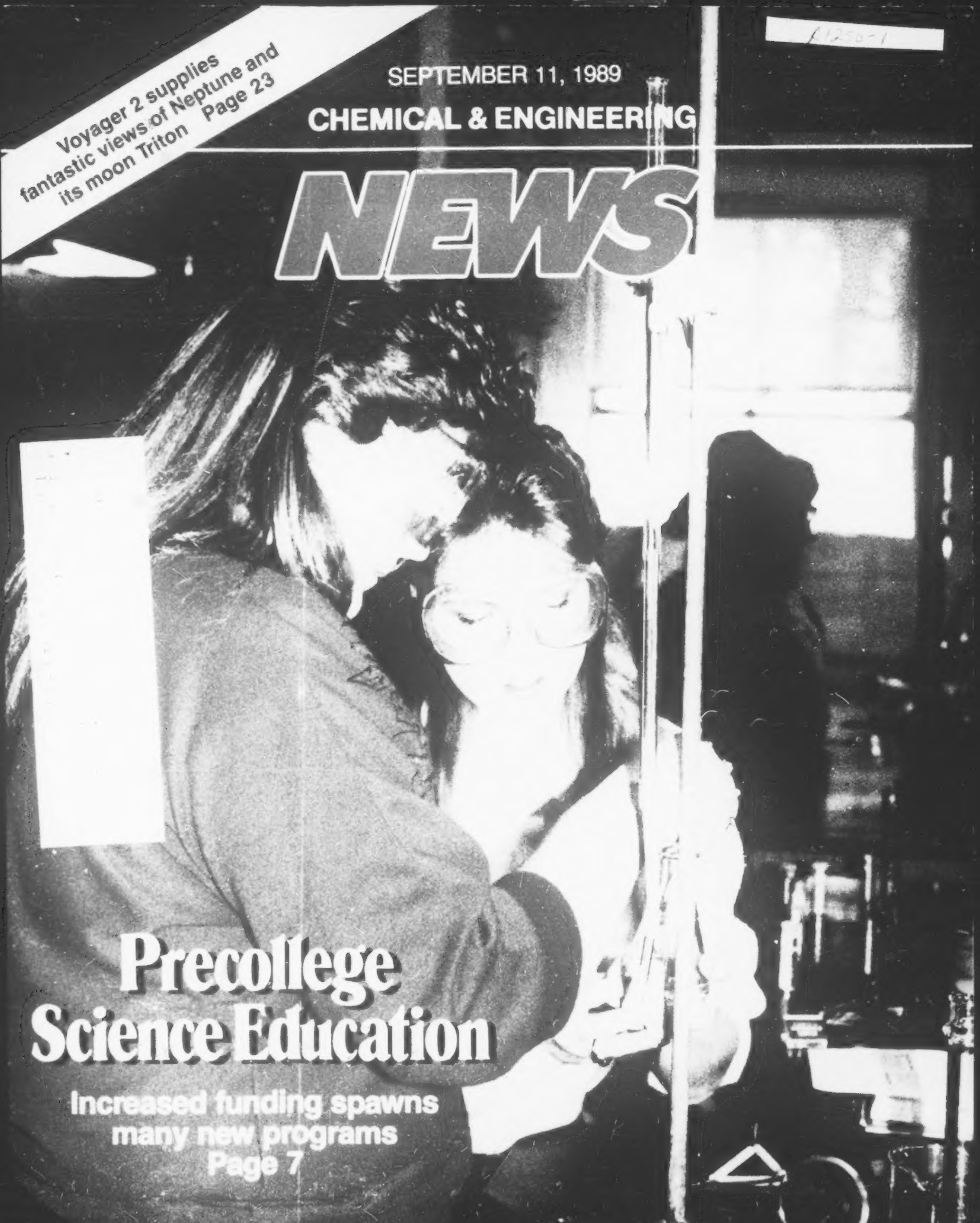
William Storck

A1250-1

SEPTEMBER 11, 1989

CHEMICAL & ENGINEERING NEWS

Voyager 2 supplies fantastic views of Neptune and its moon Triton Page 23



Precollege Science Education

Increased funding spawns many new programs
Page 7

Volume 67, Number 37
CENEAR 67 (37) 1–48
ISSN 0009-2347

CHEMICAL & ENGINEERING
NEWS
SEPTEMBER 11, 1989

News of the Week

■ Idaho has closed its borders to waste shipments from the Rocky Flats nuclear weapons plant, exacerbating the already critical problem of radioactive wastes disposal. **Page 4**

■ The Chemical Manufacturers Association says it is already taking steps with the Drug Enforcement Administration to ensure meeting President's goal of halting the flow of chemicals from the U.S. used to process drugs. **Page 5**

■ U.S. farmers should begin adopting less wasteful, costly, and polluting agricultural methods, a National Research Council study concludes. **Page 5**

■ White House has released its comprehensive plan on priorities for research on global environmental change. **Page 6**

■ Generic drug maker Lyphomed has accepted a takeover offer from Japan's Fujisawa Pharmaceutical Co., marking the first acquisition of a U.S. pharmaceutical company by a Japanese firm. **Page 6**

Cover: Students take part in precollege program at Tennessee Technological University

Letters 2

Concentrates

Business 13

Government 18

Science/Technology 21

The Department

Newscripts 48

Business

Hydrogen peroxide producers are adding capacity, mostly to meet demand in pulp and paper but also for new and growing applications. **Page 15**

Government

Most of the cost of cleaning up the environment over the next decade will have to be shouldered by state and local governments, a recent report forecasts. **Page 19**

The likelihood of acid rain legislation this Congress has spurred EPA and state air control groups to weigh programs for meeting the new requirements. **Page 20**

Science/Technology

Voyager 2's near perfect encounter with Neptune provides scientists with abundance of data about fundamental aspects of mysterious planet. **Page 23**

Education

Teaching polymer chemistry at small colleges is focus of summer course held at Rensselaer for selected chemistry faculty. **Page 30**

Baltimore City Elementary Schools Science Expo culminated citywide program of science fairs involving 5000 students, 100 schools. **Page 31**

ACS News

ACS announces 1990 winners of its national awards, most of whom will be honored next year at Boston ACS meeting. **Page 32**

News Focus

Increasing funds from National Science Foundation coupled with innovative activities by industry, universities, and government agencies have brought new vitality to precollege science and math education programs. **Page 7**

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LETTERS

Supercomputer estimations

SIR: In your interesting article, "Improved Access to Supercomputers Boosts Chemical Applications" (C&EN, July 17, page 29), Du Pont researchers calculated the difference in the enthalpy of formation in the gas phase of *m*-diaminobenzene and *p*-diaminobenzene using a supercomputer. It is gratifying to see that the supercomputer value of 12 kilojoule mol^{-1} verifies the experimental value of 11 ± 4 kJ mol^{-1} for the crystal phase. The experimental data and estimates of their accuracy are available in "Thermochemical Data of Organic Compounds" by J. B. Pedley, R. D. Naylor, and S. D. Kirby. The article does not state the estimated accuracy of the supercomputer value, but there are few estimations methods that give accuracies to better than 4 kJ mol^{-1}.

Heats of formation of chlorofluorocarbons were also estimated via supercomputer. It would be interesting to see how these values compare with the extensive set of enthalpies of formation of these compounds recently published in the "TRC Thermodynamic Tables—Non Hydrocarbons."

Kenneth N. Marsh, *Director*
R. C. Wilhoit
Associate Director
Thermodynamics Research Center
Texas A&M University

Educating the public

SIR: Michael Heylin's editorial "Chemists' Pride" (C&EN, May 1, page 5) was right on target. As a second-generation chemist I have experienced the change of the general public's attitude toward the profession. Is there a 30-year-old profession that hasn't changed?

I have become complacent about attending public relations meetings sponsored by ACS, but I have a suggestion for our profession. The public is very uneducated about chemistry. Sodium chloride, H_2O, sodium bisulfate are foreign terms. If it's foreign, most people get scared. It's human nature, not rampant ignorance.

My suggestion is based through our association. Chemists need to educate the public. The public receives most of its education from television. Chemists need to be polished in presenting their work and themselves. Take a Ph.D. who has won hundreds of awards, written thousands of articles, and is well esteemed in our profession versus a high school student who has just won the county science fair award. People relate more to the student and his or her work than to the professor.

I am requesting chemists to input chemical names whenever possible into the product they develop, especially if the product is "clean." A clean product is one where no possible environmental liability can take place. Soaps need to stress the chemical names like surfactants. Instead of printing fragrance put "chemical fragrance." I don't know what a nonchemical fragrance is. We're reestablishing a good connotation—"fragrance" with the term chemical.

All legitimate pharmaceuticals need to have the label, "This product was invented by a chemist. On behalf of ACS we hope you enjoy it."

Saturday mornings, have an ACS-sponsored cartoon. Mr. Magoo giving a very fundamental lesson revolving around chemistry.

The point is there are hundreds of ways to emphasize the positive aspects of our profession. Let the general public know that chemists can solve our chemical problems.

Don T. Pearson
President
Smiseth Corp.

Upper atmosphere

SIR: I welcome the opportunity to join Roland Beck (C&EN, June 26, page 62) and others who look skeptically on the chlorofluorocarbon hypothesis as the explanation for an ozone hole in the upper atmosphere over Antarctica.

Seldom has such unquestioning acceptance of a theory come from such diverse scientific quarters without a more critical investigation of alternative hypotheses. It seems ironic that we should be spending millions of dollars (in finding substitutes for CFCs) to apply an untested remedy to one serious environmental problem, while balking at the cost of using technology known to remedy another, namely smog. The ozone hole is an important, perhaps a life-threatening, problem; but are we prudently allocating and prioritizing our resources?

The distribution of ozone might be related to the distribution of charged particles, including solar protons, and radionuclides in the upper atmosphere. Before the atom bomb was developed, it was proposed that fission products distributed locally in the upper atmosphere could be used as a weapon, to remove the protective ozone layer, to destroy life beneath. Although we receive some news about radioactive fallout from bomb tests, Three Mile Island, Chernobyl, satellites, and so on, and about radon daughters rising from the earth, we hear little about the distribu-

States Bear Growing Share of Environmental Cleanup Cost

Report finds that most states are hard-pressed to meet the expense of existing programs, predicts bulk of burden will fall on states in the future

Between now and the year 2000 the cost of environmental protection may grow almost $21 billion in real terms, and state and local governments are going to have to bear the bulk of that burden, says the National Governors' Association in a recent report. They are already bearing a growing share of the burden, and most states are struggling to meet the cost of existing environmental initiatives.

The report points out that state environmental programs were the recipients of 28% of the Environmental Protection Agency's $1.8 billion operating budget in 1979. Within 10 years the states' share has dropped to 18% and EPA's budget has fallen to $1.7 billion. Although many states have increased their appropriations from general revenues for environmental programs, there often isn't enough money available to fund them fully.

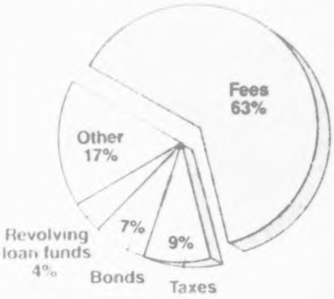
Given the gap between the cost of environmental protection and the resources available to pay for it, the National Governors' Association surveyed the 50 states to find out how they were coping. Forty-six states responded to the survey, the results of which are detailed in the report, "Funding Environmental Programs: An Examination of Alternatives."

According to the report, the most widely used alternative to federal grants or general revenues is a fee, followed by taxes, bonds, and revolving loan funds. A number of miscellaneous alternative financing mechanisms also were identified in the survey, including fines and penalties, recoveries from responsible parties, private contributions, lottery proceeds, investment income, and loan repayments. The total amount raised through all these mechanisms in 1988 was about $3.2 billion. About 92% of the proceeds were dedicated to a specific environmental program.

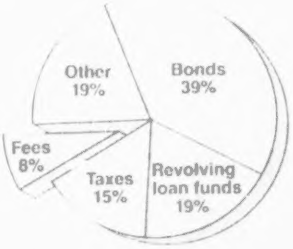
Fees don't raise much money, only $240 million, or 7.5%, of the reported total, but they certainly are popular. The survey found 272 fee programs in use in 43 states. Thirty-three states reported using 89 hazardous and solid waste fee programs, including application and permit, disposal, and generation fees, that generate more than $96 million annually. Twenty-three states collect roughly $56 million each year through a total of 51 programs that impose permit or emissions fees on sources of air pollutants; and 30 states use fee programs to finance water quality control activities. Those states derive about $46 million annually from 86 programs.

Wisconsin leads all states in the number and variety of fee programs. It has 32 different programs that raise about $10 million annually. The state has several landfill disposal fees, new car and waste tire fees, and an acid deposition fee in addition to air permit fees. In the water area alone, it imposes a laboratory certification fee; sanitary permit and license fees; a storage tank installation fee; a septic system fee; a well drillers' permit fee; a water regulation permit fee; a pump installers' permit fee; dam safety fees; a petroleum cleanup surcharge fee; pesticide and fertilizer sales fees; aquatic nuisance fees, as well as an acid rain-aquatic nuisance fee; a compensation fee for wells; and a soil and plant additives fee.

Fees most widely used way to fund state programs . . .



. . . but generate the least amount of revenue



Total 1988 = $3 billion

Source: National Governors' Association, "Survey on Alternative Financing Mechanisms for Environmental Programs, 1989"

The survey found 37 tax programs in use in 16 states that raise about $490 million annually. Of that amount $152 million is devoted to hazardous and solid waste programs, $104 million to air programs, and $88 million to water programs. The remaining revenues couldn't be classified as to end use, according to the report. California raises the most, $104 million annually, through taxes. Vehicle registration and driver's license taxes raise $46 million, and local district charges for air operating permits raise another $58 million. All of the money goes to air programs.

Washington is alone so far in financing its water quality programs through the imposition of a "sin tax" on tobacco and cigarettes. But the report notes that to cover revenue needs, other states have indicated that they are considering new laws that will increase sin taxes. These taxes are popular for three reasons, the report explains. "First, lawmakers have found that products such as liquor and cigarettes are relatively inelastic goods; thus they can be taxed without a significant fall in consumption. Second, because the tax base is large, the revenues generated are usually substantial. Finally, taxing these products is generally more palatable to taxpayers than raising other taxes."

Bonds are the most lucrative of the alternative financing mechanisms examined in the report. Twelve states raised almost $1.3 billion through the issuance of general obligation ($850 million) and revenue ($403 million) bonds to fund environmental projects.

But bonds have their drawbacks. General obligation bonds usually require legislative or voter approval, which isn't always a certainty. And as the report points out, the 1986 tax reform act imposed a number of restrictions on revenue bonds, making them much more difficult to issue. Many of the act's restrictions, the report says, are directed at projects that involve both public and private participants, such as solid waste treatment plants built through public revenue bonds. These projects often have proved to be more cost-effective than facilities financed and operated solely by the government, the report says.

Revolving loan funds, which require large infusions of up-front money, totaling $597 million are in use in 13 states. The majority of these funds, according to the report, were established mainly to cover the cost of completing municipal wastewater treatment systems required by the Clean Water Act of 1987.

Janice Long

States preparing for acid rain legislation

A new clean air law is looking more and more likely from the 101st Congress. Several legislators have submitted different bills for updating the nearly 20-year-old law, and even the Administration has come forth with a proposal. One of the main functions of any new clean air law will be reduction of acid rain. And in a rare burst of governmental foresight, the Environmental Protection Agency and state air control organizations are already working on having programs in place able to meet the new requirements.

Beginning in 1984, EPA provided several states with a total of nearly $3 million to develop future acid rain control strategies. The 47 projects funded provided the start for what became known as the State Acid Rain (STAR) Program. This was a unique program because it responded only to the threat of legislation, not to a law already enacted. EPA has recently released reports describing the results of the program and providing guidance for all states on how to cope with the impending law.

Controlling acid rain by significantly reducing industrial emissions of sulfur dioxide and nitrogen oxides that are the precursors to acid rain presents states with a problem of scope and distribution they have not faced before. Existing state regulatory authorities are designed to settle in-state pollution problems, not interstate problems. And the problem is further complicated by the multistate operations of many pollution emitters.

Not knowing just how Congress is going to require them to control acid rain, the states have four control strategies in mind. A source-based program would restrict the amount of pollutants from each source, say plant or automobile. An emission-based program would focus on total emissions over a defined area. A third type is pollutant loading based, under which each pollutant would have a set concentration limit in the environment. Fourth, an environmental effects-based program would protect the most sensitive people, plants, or animals from the effects of pollution.

The type of program, then, that Congress chooses will influence how the states respond, and the STAR program has examined the impacts of each. Issues of equity and efficacy have been studied, as have the problems of how an acid rain program will affect existing air programs, the involvement of multiple agencies in setting up a control program, and interstate coordination.

One aspect of acid rain control the states are considering seriously is energy conservation. A number of studies have been performed to figure out how much energy, and consequently pollution, can be cut by conservation. STAR participants point out that conservation has a short payback period and eliminates, or at least defers, industry needs for capital construction of facilities. However, there are some problems. It seems that the first generating units that would be turned off would be the more expensive new and cleaner units. Also, utilities must make some money by selling electricity and this would be curtailed with strict conservation.

In the end, it probably will be some combination of conventional control technologies that will be used. These include scrubbers, fuel switching, and clean coal technologies. Fuel switching entails replacing high-sulfur coal with oil, natural gas, or low-sulfur coal. New technologies for cleaner burning fuels, such as fluidized-bed combustion, advanced fuel gas desulfurization, and integrated gasification combined cycle turbines, are promising, but may run into problems from existing air rules or from reluctance of companies to invest in unproven methods.

Even with the control strategies somewhat in focus, states will not be able to instantly implement technologies to drastically cut sulfur dioxide and nitrogen oxides emissions. States participating in the STAR program indicate that it could take at least 24 months, and preferably 30 months, to develop full control plans once Congress has passed legislation.

David Hanson

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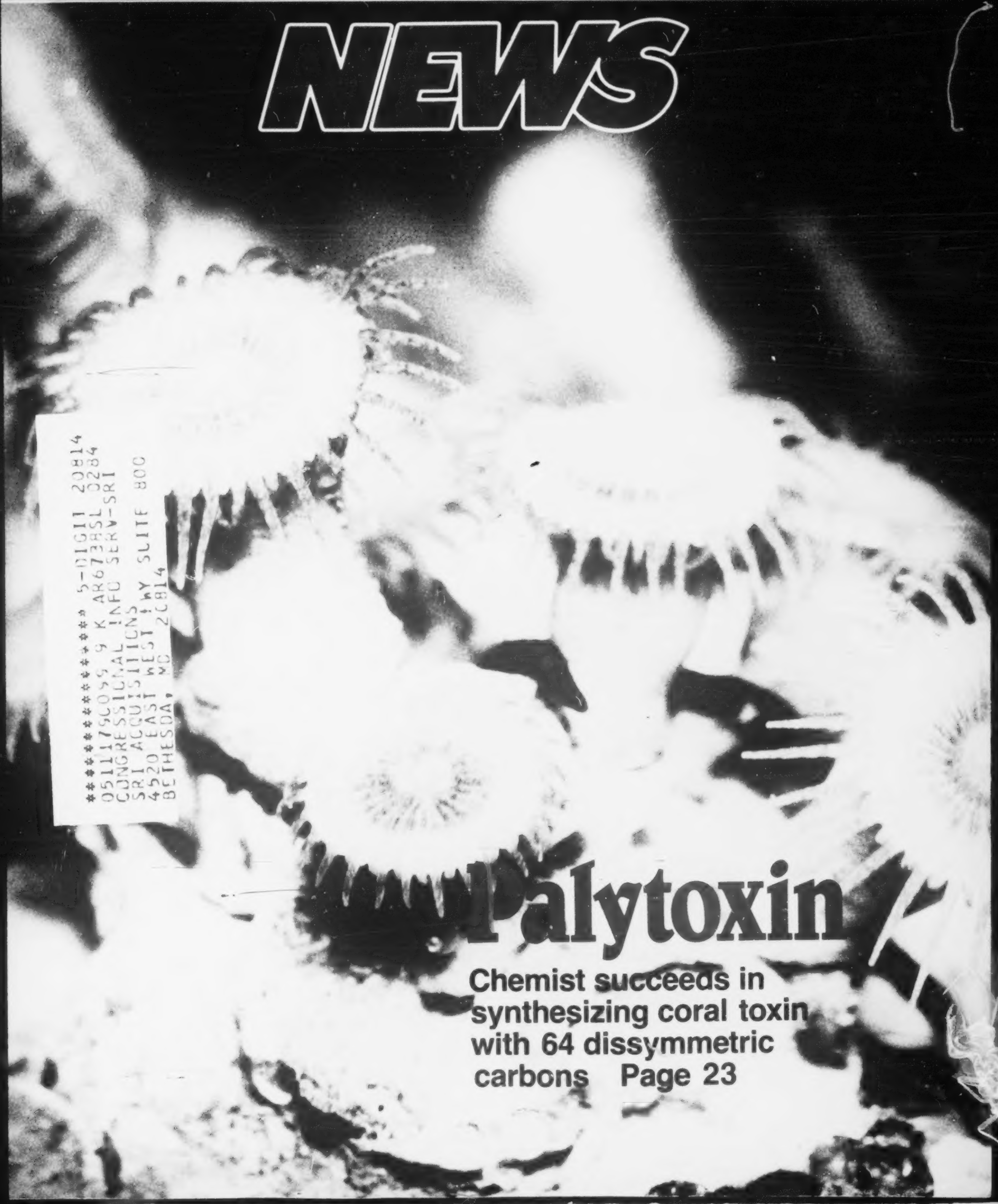
SEPTEMBER 18, 1989

CHEMICAL & ENGINEERING NEWS



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Palytoxin

Chemist succeeds in synthesizing coral toxin with 64 dissymmetric carbons Page 23

CHEMICAL & ENGINEERING
NEWS

Volume 67, Number 38
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SEPTEMBER 18, 1989

News of the Week

- **Seventy national delegations meet to negotiate bilateral chemical weapons agreement. Page 4**
- **Global environmental chemistry issues prominent at ACS Miami Beach meeting. Page 5**
- **Chemists at Brookhaven National Labs discover new form of "hot" fusion. Page 6**
- **New approach to drug efficacy testing for AIDS patients endorsed by medical panel. Page 6**
- **Savannah River reactor in South Carolina to resume tritium production in late 1990. Page 7**
- **Dow Chemical, Sikorsky Aircraft division of United Technologies agree to joint composites venture. Page 7**
- **Polymerization processes unveiled by GE chemists promise new carbonates applications. Page 8**
- **New survey of biomass of North American forests shows 75% less than previously calculated. Page 8**

Business

Avtex Fibers faces some tough tests as it deals not only with charges that its Virginia plant polluted river with PCBs but also with profitability problems. **Page 11**

The $470 million Bhopal settlement is held up in a review process by India's Supreme Court amid charges that government sold out victims in settlement. **Page 15**

Government

President Bush's proposed global-change program aims to coordinate environmental research of federal agencies in effort to provide policymakers with sound scientific information on environment. **Page 18**

Science/Technology

New IUPAC program, "Chemistry in Action," calls for organization to involve itself in a number of chemistry-based topics that are global in context. **Page 25**

Software for 3-D molecular structure searching offers powerful new dimension for molecular modeling, rational design of drugs. **Page 28**

Awards

ACS award winners: Allinger, Bercaw, Bishop, Bockrath, Brossi, Chen, Field, Kinsey, Fraser-Reid, and Freiser. **Page 35**

Cover: Organism *Palythoa toxica*, source of extremely poisonous palytoxin, is actually a coral found in single tide pool in Maui. Photo by S. Arthur Reed of the University of Hawaii, Manoa

Letters 2

Concentrates
Business 9
Government 17
Science/Technology 20

The Departments
ACS News 33
Meetings 39
Newscripts 56

Cover Story

Total synthesis of coral toxin palytoxin, a giant molecule that weighs in at 2860 daltons and has 10^{21} possible isomers, achieved by Harvard chemists. Page 23

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LETTERS

Encourage women scientists

SIR: The concept of exposing high school students to applied science at Rose-Hulman Institute of Technology by Noel Moore and Operation Catapult (C&EN, July 10, page 25) deserves praise. This summer program is able to accomplish two very important objectives: promoting science while motivating young people.

One problem that concerns me about the implementation of this concept into an actual working program is that only half of the eligible high school population is offered this summer opportunity. You see, women are currently ineligible to participate because the college where the program is held is not coeducational. It is a shame that women are denied participation in this unique summer program on the sole basis of gender.

Young women with an interest in science are just as keen as young men in pursuing high-quality, unique, summer science programs. There are currently few programs of this caliber available, and if I were still a high school student, this program would be high on my priority list. I would experience real disappointment at being denied participation simply because I lacked a Y chromosome.

My suggestion is to make this program available to all promising students of science. (After all, there seem to be so few of them to begin with.) Here are three bold suggestions:

- Declare that both summer sessions will be coeducational and invite women to participate in either session. If necessary, employ one or more females to act as dormitory chaperones.
- Declare that one summer session is for men and that the other is for women.
- Establish a sister program at a nearby college that will offer Operation Catapult to women.

If for ideological or financial reasons these options are unfeasible, then I am truly disappointed. As professionals, we need to encourage all young people in the sciences, no matter what their gender.

Christina Schwerdtfeger
Los Angeles

Energy consumption growth

SIR: The early euphoria over the announcement of the discovery of room-temperature fusion led the press to speculate about the enormous benefits of a new source that might produce "energy that was too cheap to meter." The tragic implications of such a discovery have not been examined.

Every sector of society thrives on growth. The dominant belief is that we need more people, more jobs, more materials consumed, and more energy consumption per person per year. Annual growth rates of only a few percent characterize a recession and rates in the double-digit range are said to be healthy or robust. The availability of unlimited energy would seem to remove one of the major limits to growth so that rates of energy consumption could grow indefinitely.

The problem is this. Essentially all the energy we consume appears ultimately as heat in the environment. Human activities today put into the global environment about 10^{-4} of the energy the sun puts into the global environment. Simple arithmetic shows that a factor of 10^4 can be gained by growth through only 14 doubling times, at which point the arithmetic would say that human activity was putting as much energy into the global environment each day as the sun puts in. Such a situation would be much worse than intolerable.

Question: If we had abundant low-cost energy, is there any evidence that humans could get together to stop the growth of the rate of energy consumption in order to save ourselves?

Albert A. Bartlett
Professor Emeritus
University of Colorado, Boulder

Cold fusion, superconductivity

SIR: Cold fusion and superconductivity (C&EN, July 10, pages 5 and 19) are the hottest items that have hit the scientific community in 40 years.

Between backswings and backcasts, please let me comment on these articles. In the first article, General Electric Co. and the University of Utah sign a joint agreement to study and develop cold fusion phenomenon. GE has a long history of multilateral agreements with government and academia in cooperative research, especially nuclear energy. However, it seems to have stolen the show in landing a bilateral agreement with Utah "by positioning itself at the cutting edge of research in the exciting new area of energy development with the opportunity to license any promising technology."

However, nuclear physicist Martin Deutsch of Massachusetts Institute of Technology speaks very disparagingly of this marriage. But this sounds like sour grapes. The jury is still out on the viability of cold fusion. In the meantime GE's agreement with Utah is a legal/administrative coup—especially since most of the high-powered industrial,

Avtex Fibers Hit by Mounting Pollution, Profitability Problems

Charges that Virginia plant is discharging PCBs into river coupled with earlier charges, continuing profits squeeze threaten fiber maker's health

Marc S. Reisch,
C&EN Northeast News Bureau

Avtex Fibers has displayed a remarkable ability to bounce back in the face of adversity. The cards, though, just seem to be stacked against the company. Now Avtex faces charges from the Virginia State Water Control Department that its Front Royal, Va., rayon plant is polluting the South Fork of the Shenandoah River with polychlorinated biphenyls (PCBs). The Shenandoah is a tributary of the Potomac River, a major water source for the Washington, D.C., area. Late last month the state police seized documents from the Avtex office as part of a criminal investigation to determine whether the company deliberately discharged PCBs into the river.

Virginia Attorney General Mary Sue Terry continues to pursue Avtex and has asked Virginia State Circuit Court Judge Theodore J. Markow in Richmond to shut down the Front Royal plant unless Avtex can prove it can afford to spend the millions of dollars the state estimates it needs for environmental repairs.

The latest charges are in addition to a slew of existing charges of air, water, and safety violations against the plant. They include a $9.1 million toxic wastewater cleanup ordered by the Environmental Protection Agency, aimed at Avtex and former plant owner FMC, and $9.3 million in repairs for numerous environmental and worker safety violations ordered by various state agencies, aimed at Avtex only. The chances that the plant will eke through its latest troubles and continue to operate are slimmer than ever.

Figuring out exactly what is happening at Avtex is not an easy task. Because the company is privately held, very little financial information about it is available. John N. Gregg, Avtex chairman and principal stockholder, isn't commenting about the firm and its plans. At one time, particularly when he worked on behalf of the U.S. textile industry—lobbying in Washington for the Fiber, Fabric & Apparel Coalition to secure passage of legislation to slow the importing of textiles—he frequently was accessible to the press. However, he hasn't been available recently because of illness.

Gregg did appear in a television interview the day the state identified Avtex as the source of PCB contamination. According to the *Front Royal-Warren Sentinel*, Gregg said that closing the plant "makes no sense." He added that there isn't any PCB contamination now and that any contamination that occurred was in the past.

Crutchfield: rising raw material costs

Avtex spokesman Jeff Nelson says the company is still analyzing the state's data on the level of PCBs in the river and has no comment at this time. According to Thomas M. Selvey, program manager for the Virginia Water Board and author of the agency's report on PCB contamination at Avtex, there are numerous electrical transformers on the sprawling 439-acre site that could contain PCBs. The water board took nine site samples and found that five of them tested positive for PCBs. One of these samples taken near a loading platform registered a PCBs contamination level of 78 ppm. The water board also sampled riverbank soil where water laps during high river flows, says Selvey. No PCB contamination was found up river from either Avtex's storm sewer or treated waste discharge pipes and the water board found no PCB contamination coming from either of these two sources.

But samples taken 200 feet down river from the two discharge pipes showed riverbank PCB contamination levels of 15.6 ppm, at 1000 feet 10.7 ppm, and at 1400 feet 38.3 ppm. Selvey's report concludes that "based on these samples, all sources of contamination can be eliminated except Avtex Fibers Inc. in the vicinity of outfalls [from the two pipes]."

The evidence appears damning but Avtex's Nelson says he is not convinced that the company is the source of the PCB contamination. Nelson adds that in June EPA discovered some PCB leaks outside the plant and that Avtex contractors are attending to those leaks now.

And Selvey says that the water board found no active source for the PCBs.

Avtex's Gregg has been resourceful in the past. Three times he has managed to resuscitate what seemed a terminally ill rayon operation. In 1976 he engineered a leveraged buyout of the former FMC Fibers division when no one else appeared to want the money-losing operation. In 1986 he negotiated salary concessions from the plant's 1300 unionized workers and avoided a shutdown. And in November 1988 he closed the plant for three days until the Department of Defense and the National Aeronautics & Space Administration helped the company come up with $20 million.

Some would say that when Gregg closed down the plant in November he played his trump card. Avtex, it seems, was, and still is, the only qualified supplier of carbonizable rayon for missile and rocket nozzles. Manufacturers of those nozzles have only limited stocks on hand and were Avtex to shut its doors, the U.S. space program would experience delays. Avtex rayon is carbonized, impregnated with epoxy, and used to form exhaust nozzles for the space shuttle's rocket boosters. Carbonizable rayon also forms the heat shields for the leading edges of the shuttle's wings. Carbonizable rayon shortages would affect defense missile production as well, including the MX missile and the Midgetman missile.

Morton Thiokol is a major user of Avtex carbonizable rayon. With prompting from NASA and DOD, Morton Thiokol helped Avtex to reopen its Front Royal plant last November with an advance payment for the rayon necessary to build a larger stockpile. Recently it placed another order for 1 million lb of carbonizable rayon. But whether Avtex can keep the plant in operation and pay out millions of dollars in cleanup costs aside from its potential PCB cleanup obligations is open to conjecture.

At one time Avtex had sales of about $300 million annually, according to industry sources. This included sales of not only rayon, but also polyester filament produced at Lewistown, Pa., and polypropylene staple, also produced at the nearly 50-year-old Front Royal plant. Sales surely have dropped. In July the company ceased production of textile-grade rayon fibers, including high wet modulus rayon—a highly elastic, high-crimp fiber preferred by textile producers over regular rayon because of its comfort, durability, and stability even when wet. By discontinuing production on five of eight rayon lines and by laying off some 500 of about 1300 employees, Avtex hoped to reduce the amount of zinc and sulfates discharged into the South Fork of the Shenandoah River, thereby forestalling an earlier threat from the state of Virginia to shut down the plant entirely because of pollution problems.

Avtex says it did not shut down production of textile-grade rayon solely because of environmental problems. The fiber also wasn't profitable, it points out. Raw material costs have risen faster than they can be recovered. The company admitted as much last September when marketing president James E. Crutchfield told C&EN that long-term contracts along with fierce market competition severely limited Avtex's ability to pass along raw material increases to customers (C&EN, Sept. 19, 1988, page 16). He cited, particularly, rising prices for caustic soda and dissolving pulp. In 1988, caustic soda prices rose 40% over 1987, according to the Department of Labor. At the same time, rayon prices rose only 9.7%. In June, the latest month for which statistics are available, caustic soda prices were up 31% from June 1988, while rayon fiber prices were up 10% higher for the same period.

Last November when he temporarily shut down the Front Royal plant, Gregg cited raw material costs as the most important factor. "Ironically, we are closing with a backlog of orders. But at the price we had to pay for pulp, we weren't making a profit," Gregg stated at

BASF, Courtaulds ready to step in with rayon

When Avtex Fibers shut down its textile fiber production in July, it withdrew a supply of at least 80 million lb of high wet modulus fiber from the textile apparel and home furnishings trade. Competitors BASF and Courtaulds are attempting to fill the void.

According to BASF Fibers director of rayon products R. Jack Higdon, the company is planning to double its current capacity of 20 million lb of high wet modulus fiber. However, the additional capacity will not be available until mid-1990. This represents little solace for fabric weavers, who currently have orders to fill and must scramble to find sufficient amounts of suitable rayon yarn or substitutes. Still it does offer some hope for the future.

Higdon says that BASF will run its rayon lines at capacity to meet market demand. Industry sources estimate BASF's rayon fiber capacity at 115 million lb at its plant in Lowland, Tenn. Higdon adds that BASF has no firm plans to add new capacity, but is considering that option for the future.

At Courtaulds Fibers, the North American arm of the diversified British fibers supplier, Derek F. Twogood, president, says the company will be increasing its rayon capacity 20%. This represents additional lines at plants in both Mobile, Ala., and Cornwall, Ontario, Canada. Industry sources put the U.S. plant's capacity at about 202 million lb. Courtaulds' investment at its Mobile facility will amount to more than $10 million and will result in a new production line at the plant.

Twogood says, however, that Courtaulds has no direct replacement for the high wet modulus rayon capacity lost with the Avtex shutdown in July. Courtaulds has, he claims, perfected a 1.1-denier rayon fiber for light print cloth. As a result, the company hopes to supply the 1.1-denier product as a replacement for high wet modulus fiber.

October will be a critical time for rayon demand as textile makers gear up production, Twogood points out. There will be a few headaches, he admits. Inevitably, many will switch to cotton. But the Avtex shutdown "will not be catastrophic," he says, for between Courtaulds' U.S., Canadian, and U.K. rayon fiber operations and BASF's resources, the industry will get most of the rayon supplies it needs.

Rayon prices have been stable relative to competitive fibers, but squeezed lately by raw material caustic soda

Producer price index[a]	1988	1987	1986	1985	1984	1983	Annual change 1987–88	Annual change 1983–88
Rayon	105.3	96.0	93.2	94.5	97.3	97.3	9.7%	1.6%
Raw cotton	95.5	105.8	88.0	97.7	113.5	114.0	−9.7	−3.5
Polyester	88.3	82.0	81.5	87.4	98.3	95.5	8.3	−1.6
Caustic soda	74.4	53.0	49.8	60.8	59.9	75.5	40.4	−0.3

a 1982 = 100. **Source:** Department of Labor

the time. The pollution problems, he said, "played a small part in our decision to close." Gregg also charged that the company's major domestic competitors, BASF and Courtaulds, imported dissolving pulp from South Africa, allowing them to undercut the price Avtex had to pay for the higher quality U.S. and Canadian pulp it uses in its plant.

BASF and Courtaulds also market other fibers and thus are not tied to the rayon fiber business cycle. BASF, for instance, had 1988 worldwide sales of about $25 billion. Its North American fibers unit, which includes nylon, acrylic, and rayon, contributed some $912 million to this total. Courtaulds' fiscal 1988 worldwide sales amounted to about $3.9 billion and its worldwide fiber sales $670 million, including acrylic, acetate, and rayon.

Front Royal plant has had checkered history

The Front Royal rayon plant has a long and, more recently, troubled history. It was built in 1938 by American Viscose Co., a subsidiary of the U.K.'s Courtaulds. However, during World II Courtaulds had to give up American Viscose when England pledged its subsidiary's stock to the U.S. government as part of the lend-lease agreement. During the 1940s and 1950s American Viscose was a publicly held company and employed as many as 3000 people in the Front Royal plant. The company was profitable during these years as well as in 1961 when it sold the plant to FMC. However, in 1976 when John N. Gregg, then FMC Fibers division vice president and now Avtex Fibers' chairman and principal stockholder, engineered its purchase to form Avtex, the plant was in the red. Avtex has operated the plant profitably until recently, when it was beset by cost and pollution problems.

In addition to competition from BASF and Courtaulds, Avtex faces the problem that textile manufacturers resist higher fiber prices. Textile makers can substitute cotton for rayon. They began to do so after Courtaulds suddenly closed down its rayon fiber operation in November and, because of the uncertainty of supply created, were prepared when Avtex shut its textile-grade rayon fiber production in July.

Avtex long has believed that its strong suit is its position as a specialty fibers producer. However, the fact that Avtex was a primary supplier of a specialty grade of rayon for the textile industry hasn't been a panacea. In addition to its carbonizable rayon, it is the major source of high wet modulus rayon fiber. Its capacity for this fiber is estimated to be about 80 million lb. Industry sources put BASF's high wet modulus rayon fiber production at about a fifth of Avtex's. Because of its high wet modulus fiber, Avtex has been the preeminent supplier of rayon for the apparel industry, according to industry sources. This is little comfort, however, if textile makers resist paying the price and can fall back on readily available substitutes.

Still, Avtex believes that rayon sold from its three remaining lines will command a price allowing it to turn a solid profit, according to Nelson. In addition to carbonizable rayon, the company also sells fiber for medical uses, he says.

Avtex has been forced to retrench before in the face of declining demand. It shut down an estimated 55 million lb acetate yarn plant in

The 'Accoun-Table' by noted Swiss cartoonist and satirist Louis Mermet.

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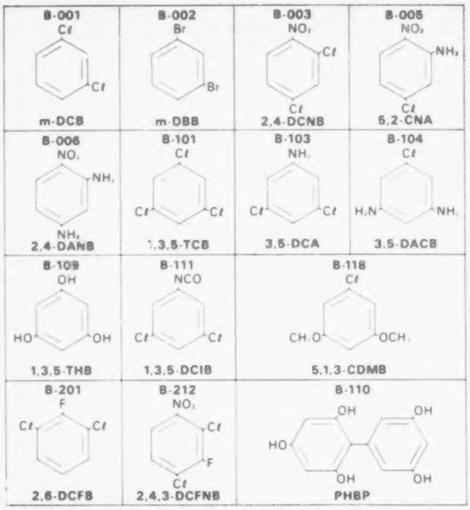

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Meadville, Pa., in 1985. Hoechst Celanese and Eastman Chemical are now the only producers of the fiber. In many instances polyester yarn has supplanted acetate in apparel and home furnishings applications. That same year Avtex sold its 1.5 million lb vinyon fiber operation to Celanese (now Hoechst Celanese).

Avtex has had a profound effect on Front Royal and the surrounding counties from which it draws its employees. When the Front Royal plant with its $25 million annual payroll almost closed three years ago, it was saved only when union employees agreed to grant the company wage concessions of more than $1.00 an hour.

Again last November employees were confronted with the uncertainty of not knowing where they would receive their next paycheck. At the time Gregg told reporters that he suffered along with them. "I have 1300 people and somebody has got to take care of them. Somebody has got to get them a job." A panic nearly took place at the Front Royal Federal Credit Union when depositors feared that the closing of the plant meant the closing of the credit union. The credit union had been founded by the local textile workers union. Today, however, it is a community credit union and not associated with either Avtex or the union.

The 500 rayon workers laid off this summer currently are seeking federal assistance under a program that would retrain workers who have lost their jobs because of imports. The Labor Department has not ruled on that request yet.

Avtex still may be able to survive. Although its Lewistown, Pa., polyester plant has a few environmental problems affecting a landfill, it is not caught up in the Front Royal controversy. Company officials say the Lewistown plant is consistently profitable. Avtex recently closed its sales offices in New York City and Charlotte, N.C., eliminating about 40 jobs. Corporate offices and senior sales and marketing personnel remain in Valley Forge, Pa. The question remains, however: Can it survive as a smaller company in the face of its environmental problems? □

Global-Change Plan To Coordinate Agencies' Environmental Research

Bush program directs spending for global-change research program; goal is to give policymakers sound bases for decisions on environment

Given the mounting evidence that human activities are changing the environment on a global scale, the Bush Administration has devised a strategy for research on global change. The plan—released by the White House in early September—embodies a significant attempt to coordinate federal agency research on monitoring, understanding, and ultimately predicting global change (C&EN, Sept. 11, page 6).

Presidential science adviser D. Allan Bromley said in releasing the report that the plan represents both his and President Bush's commitment to increasing understanding of the complex problem. The goal of the research program is to provide a sound scientific basis so that policymakers can make decisions on global-change issues such as ozone depletion, climate warming, desertification, and acid rain.

"The U.S. Global Change Research Program" was put together by the Committee on Earth Sciences (CES), part of the President's Office of Science & Technology Policy. The committee, chaired by U.S. Geological Survey head Dallas L. Peck, consists of representatives from a dozen federal agencies.

CES members worked with the National Academy of Sciences' (NAS) Committee on Global Change to hash out priorities for the $191 million the Bush Administration has proposed spending for global-change research in fiscal 1990. That amount, spread across seven federal agencies, represents an increase of 43% over 1989 appropriations. As Congress nears its Oct. 1 deadline for finalizing the budget, it looks likely that the budget request will be enacted.

C&EN staff photo

Corell: sets up framework of priorities

The report defines the key scientific questions that global-change research must answer, surveys what research programs are now in place, and details what gaps need to be filled and what agency or agencies can best fill them. "The plan is the first time we've attempted to set up a framework of priorities within which we all agree to function," says Robert W. Corell, assistant director for geosciences at the National Science Foundation.

According to the report, the answers to three scientific questions could help distinguish changes in the global environments that are caused by humans from those that are the result of natural variability:

- What global changes have occurred in the past and are occurring now?
- What physical, geological, chemical, biological, and social processes are involved in influencing global change and its environmental impact?
- How well can global change and its impacts be predicted?

To answer those questions, Corell points out, requires scientific research at the interfaces of such traditional disciplines as physics, chemistry, geology, and biology. Accordingly, the White House plan groups research activities into seven interdisciplinary scientific elements that are ranked in terms of importance. The plan gives highest priority to research on climate and hydrologic systems, followed by biogeochemical dynamics, ecological systems and dynamics, Earth system history, human interactions, solid earth processes, and solar influences.

Within each of the main areas of inquiry, the plan assigns priorities to various research activities. For example, the role of clouds and ocean circulation and heat flux is given the highest priority under climate and hydrologic systems.

Federal agencies will spend $191 million on global-change research

$ Millions	Research focused on global change	Related research	Total
NSF	$ 53.5	$ 120.0	$ 173.5
EPA	35.3	58.9	94.2
Energy	27.2	46.5	73.7
USDA	22.7	154.2	176.7
NASA	21.5	412.6	434.1
Commerce	20.0	382.8	402.8
Interior	11.3	204.5	215.8
Defense	0	32.3	32.3
TOTAL	$191.5	$1411.8	$1603.1

Note: Proposed budget for fiscal 1990.

The research plan looks in detail at the strengths and weaknesses of current programs that address global change. Specific recommendations for agency activity in 1990—and outlines for later years—are spelled out. The National Oceanic & Atmospheric Administration (NOAA, part of the Department of Commerce), for example, would study how the circulation of ocean currents and oceanic uptake of greenhouse gases influence climate change. At the same time, USGS would study climate changes throughout Earth's history and NSF would support academic studies of Greenland ice cores for clues to conditions of ancient climates and atmospheres.

However, the integrated research plan does not include formulation of policies regarding global change nor does it address research and development of new technologies to adapt to or to mitigate environmental changes. Those gaps are serious omissions, says John C. Topping Jr., head of the Washington, D.C.-based Climate Institute.

"What the research plan recommends is important, but it doesn't focus on some very practical aspects of the problem," Topping says. "I think we need a greater flow of resources across the board." The Climate Institute has recommended that another $170 million in funds be spent in fiscal 1990 to tackle such questions as how to deal with rising sea levels caused by global warming.

The Administration has budgeted another $1.4 billion for fiscal 1990 programs that aren't strictly part of the global-change research plan but that support related activities—such as NSF's atmospheric chemistry program and NOAA's weather satellites. And although not part of the comprehensive White House research plan, the Environmental Protection Agency recently asked NAS' Committee on Science, Engineering & Public Policy to study the policy implications of greenhouse warming. The panel's report, expected in 1990, will assess technical, economic, and political factors affecting policies for mitigating or adapting to global change.

Pamela Zurer

Federal Alert—new legislation

This C&EN listing highlights legislation introduced between June 29 and Sept. 7. House and Senate bills are listed under subject area by bill number, primary sponsor, and the committee(s) to which they were referred.

HOUSE

Climate. H.R. 3143—AuCoin (D.-Ore.). Establishes national energy policy to reduce global warming. Energy & Commerce; Science, Space & Technology.

Education. H.R. 2957—Traficant (D.-Ohio). Establishes National Academy of Space, Science & Technology modeled after military academies. Science, Space & Technology.

H.R. 3122—Price (D.-N.C.). Sets up new programs at National Science Foundation aimed at combating scientific illiteracy. Science, Space & Technology.

Environment. H.R. 3030—Dingell (D.-Mich.). Administration proposal for attaining national air quality standards, controlling toxic air pollutants, preventing acid deposition. Energy & Commerce.

H.R. 3108—Eckart (D.-Ohio). States that Environmental Protection Agency must, within 10 years, require installation of maximum available control technology on major sources of air toxic emissions, establish programs to deal with emissions from area sources and sudden catastrophic release of air toxics. Energy & Commerce.

Health. H.R. 2808—Kostmayer (D.-Pa.). Requires schools to test for radon contamination. Energy & Commerce.

H.R. 3004—Evans (D.-Ill.). Provides for presumption of service connection between certain diseases experienced by veterans and exposure to toxic herbicide agents used in Vietnam. Veterans' Affairs.

H.R. 3067—Gaydos (D.-Pa.). Establishes system for identifying, notifying, and preventing illness and death among workers who are at increased or high risk of occupational disease. Education & Labor.

Museums. H.R. 3154—Brown (D.-Calif.). Requires National Science Foundation to establish science museum assistance program. Science, Space & Technology.

Patents. H.R. 2946—Kastenmeier (D.-Wis.). Provides that any invention made, used, or sold on space vehicles under U.S. jurisdiction or control shall be deemed to have been made or used in the U.S. Judiciary.

Research. H.R. 2793—Brown (D.-Calif.). Requires Secretary of Energy to develop comprehensive R&D program promoting use of hydrogen as fuel, authorizes $155 million over five years for research. Science, Space & Technology.

H.R. 2984—Roe (D.-N.J.). Gives Office of Science and Technology Policy's Committee on Earth Sciences permanent responsibility for coordinating, planning federal research efforts on global warming phenomena, calls for international agreements on funding for such research, development of safe energy technologies. Science, Space & Technology; Foreign Affairs; Merchant Marine & Fisheries.

Waste. H.R. 2485—Wyden (D.-Ore.). Allows states that have recycling program to refuse to accept wastes from states that don't, sets new standards for packaging, allows Environmental Protection Agency to prohibit use of certain packaging materials. Energy & Commerce.

H.R. 2967—Bonior (D.-Mich.). Grants state and local governments authority to enact laws to accept or reject solid waste from other states. Energy & Commerce.

H.R. 3105—Douglas (D.-N.H.). Encourages development, use of recyclable consumer plastics, sets up national labeling system for plastic consumer products. Science, Space & Technology.

Weapons. H.R. 3033—Fascell (D.-Fla.). Controls export of items necessary to produce or deliver chemical or biological weapons to countries trying to develop such capabilities, provides for sanctions against companies that aid in proliferation of such weapons. Foreign Affairs; Ways & Means; Banking, Finance & Urban Affairs.

SENATE

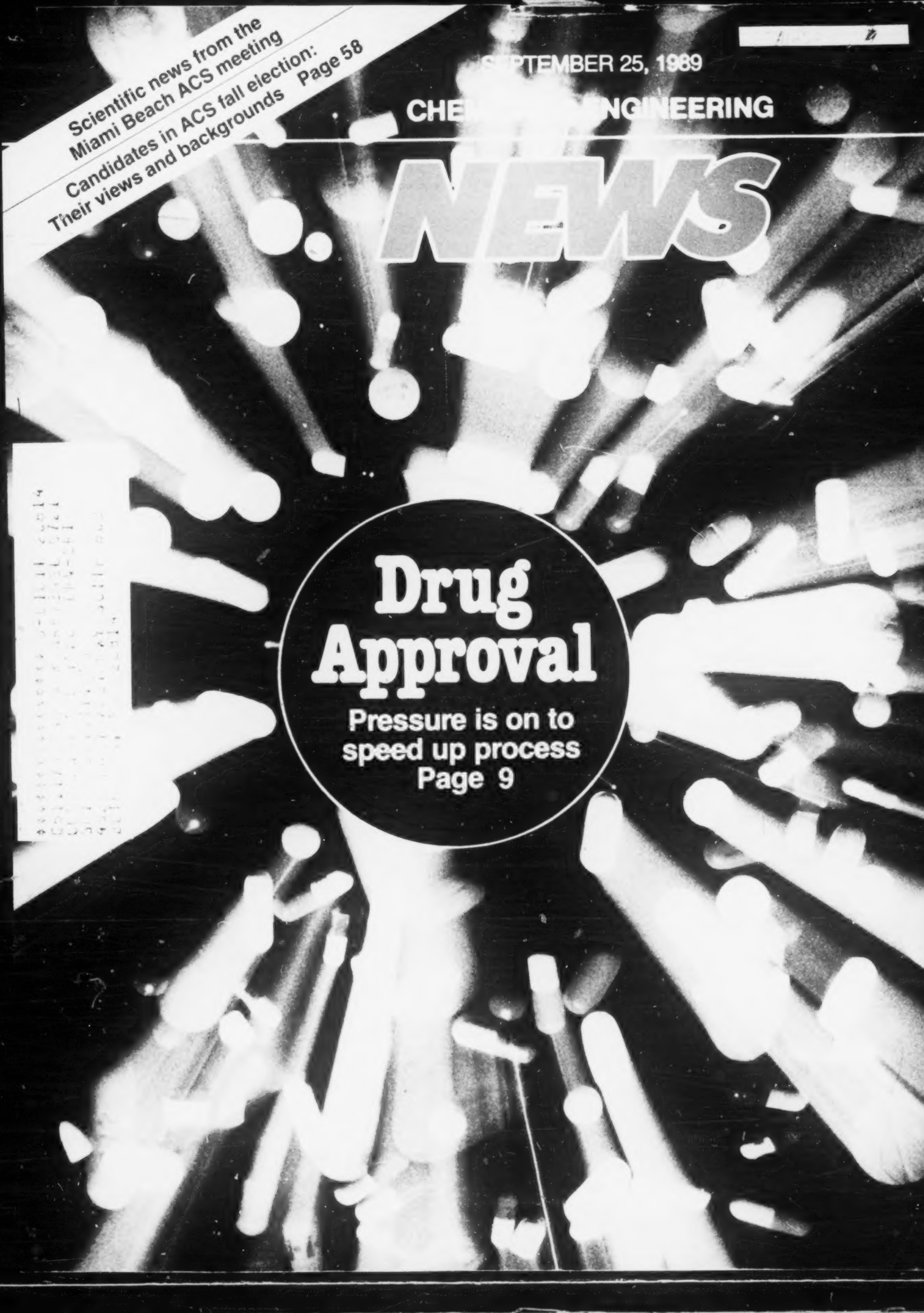
Environment. S. 1378—Gorton (R.-Wash.). Makes all persons responsible for oil, hazardous substance spills strictly liable for full costs of cleanup, restoration, or damages; provides for civil penalty equal to full costs of cleanup and restoration in cases of negligence. Environment & Public Works.

Liability. S. 1400—Kasten (R.-Wis.). Sets uniform national standards for product liability cases. Commerce, Science & Transportation.

Nuclear. S. 1304—Glenn (D.-Ohio). Requires Occupational Safety & Health Administration, National Institute for Occupational Safety & Health to regulate and oversee worker safety and health activities at Department of Energy nuclear weapon facilities; requires enforceable compliance and cleanup agreements for each facility to be in place within 18 months. Energy & Natural Resources.

Patents. S. 1529—Rockefeller (D.-W.Va.). Requires patent commissioner to draw up list of countries, including Japan, that do not adequately protect U.S. patents; states that International Trade Commission when hearing patent infringement cases involving listed countries can no longer consider any other factors; automatically implements ITC decisions in such cases. Finance.

Taxes. S. 1506—Bentsen (D.-Tex.). Limits ability of corporations to claim tax refunds resulting from leveraged buyouts and similar financial transactions involving debt. Finance.



Scientific news from the Miami Beach ACS meeting

Candidates in ACS fall election: Their views and backgrounds Page 58

SEPTEMBER 25, 1989

CHE[illegible]NGINEERING

NEWS

Drug Approval

Pressure is on to speed up process
Page 9

CHEMICAL & ENGINEERING
NEWS

Volume 67, Number 39
CENEAR 67 (39) 1–100
ISSN 0009-2347

SEPTEMBER 25, 1989

News of the Week

- **Prospects are bright for Western chemical firms in the U.S.S.R. and East Europe in the 1990s, study says.** Page 6
- **Du Pont economist forecasts that chemical production will grow more slowly in 1990, rising just 2.5% over 1989.** Page 7
- **At Australian conference, representatives of world's major chemical industries pledge to work closely with governments to secure global, verifiable chemical weapons treaty.** Page 7
- **Chemical Abstracts looks toward adding 3-D capability to the its Registry File.** Page 7
- **Rhône-Poulenc will buy the specialty chemicals unit of U.K. company RTZ Corp. and GAF's surfactants operations.** Page 8
- **Union Carbide system for making flexible polyurethane foam requires no CFC blowing agent.** Page 8

Cover: Photo by Rick Brady/Uniphoto Picture Agency

Letters 4

Concentrates
Business 14
Government 29
Science/Technology 32

The Departments
Software/Database Update 46
Meeting Briefs 52
Books 54
ACS News 56
New Products 82
Newscripts 100

Business

Massachusetts-based Cabot Corp. retrenches in effort to improve profitability; polyethylene output and prices in down cycle; plastic composites industry performance levels off in 1989. **Page 21**

Government

Effective risk communication difficult, prone to public's misconceptions, says National Research Council panel; making of synthetic heroin leads to death of one chemist, imprisonment of another. **Page 30**

Science/Technology

From the ACS meeting in Miami Beach: ring-opening polymerization method expands thermoplastics technology; modified membranes for methanol oxidation use implanted silver; lead iodide crystals grow differently in space; new techniques for stabilizing geotextiles developed; methylating reagent is stable at room temperature; simulated membrane reactor combines reactions, separation; TVA program tackles environmental concerns; and new catalytic route to commercially useful α-olefins. New nitrogen technology spurs market development. **Page 35**

Education

More from Miami Beach: improved precollege science education aim of partnerships between scientists from industry and universities and high school teachers. **Page 49**

ACS Election

Candidates for 1990 president-elect, directors-at-large, and directors for regions II and IV give views on ACS programs. **Page 58**

Awards

ACS award winners: Golden, Grasselli, Gray, Hammer, Heathcock, Hoffman, Holm, Horning. **Page 75**

News Focus

FDA is moving to shorten its drug approval process in an effort to get drugs for treating life-threatening illnesses to market faster. **Page 9**

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LETTERS

Fewer chemistry students

SIR: In response to Jeff Nissen's letter (C&EN, Aug. 14, page 3), the primary reason fewer and fewer students are studying chemistry is unquestionably the miserable employment prospects enjoyed by chemists. For example, I received my B.S. degree in chemistry from Case Western Reserve University in August 1987, and have been looking for an entry-level position ever since. My grade-point average was 2.76; admittedly not head of the class, but not miserable either. I could, of course, have gone to my pick of schools for graduate study, but there is not one employer who will hire me (with the exception of one laboratory technician position I was offered for $15,000 a year). And I personally know several other chemists who, like myself, either were utterly unable to find a job or could get a job only as a lab technician at a large local manufacturer (lab techs there start at $20,000 to $24,000—significantly higher than the salaries mentioned for many of the chemist positions for which I have been interviewed).

I am currently a provisional graduate student in chemical engineering at the University of Cincinnati because it would be very irrational of me to pursue a graduate degree in a field that offers such miserable employment prospects.

My point here is not to plead for sympathy, but rather to point out that as long as employment prospects for chemists are as bad as they are, fewer and fewer students will major in chemistry. What else do you expect?

Frank Eric Espohl
Cincinnati, Ohio

Financial support from NSF

SIR: All chemists at the National Science Foundation are pleased by the well-deserved accolades—such as the one by David Henderson of Trinity College—for Bassam Shakhashiri's leadership in revitalizing science education (C&EN, July 31, page 2).

However, I would like to correct Henderson's erroneous assertion that the REU (Research Experiences for Undergraduates) Program "has gone almost exclusively to universities." In the 45 new site programs in chemistry initiated between 1987 and 1989, 15 have gone to undergraduate institutions. The review panels selecting award recipients have drawn members from both research universities and liberal arts colleges, and rankings have been on the basis of merit, not quotas. Doctoral institutions have enjoyed a 13% success ratio in chemistry, and undergraduate schools have had a 12% rate. Interestingly, doctorate-granting departments account for 64% of applications though they account for only 33% of ACS-accredited departments at the bachelor's level—reinforcing an old NSF adage that overall success closely parallels application pressure.

Chemistry funding for Research at Undergraduate Institutions (RUI) has grown from less than $1.2 million in 1984 to an average annual investment of $3 million today, despite less than inflationary growth in the division's budget. Total financial support for undergraduate research as an integral part of undergraduate education is up fivefold since 1981, and is still growing. Although Henderson is surely correct that the exemplary record of our nation's liberal arts colleges in producing future scientists warrants strong, continued NSF support, perhaps the financial support already available from NSF is more substantial than he realizes.

Kenneth G. Hancock
Deputy Director, Chemistry Division
National Science Foundation
Washington, D.C.

Nuclear power

SIR: Harvey Wasserman's letter (C&EN, June 5, page 2) regarding the death of nuclear power as a viable energy source is but another example of the frustrations facing our nation. In the same issue of C&EN, a business concentrate (page 8) states that in 1988 nuclear power plants produced one third or more of the total electric power in 11 countries, up from eight countries in 1987, and that France received the greatest percentage, 70%. It also states that in the U.S., nuclear accounted for about 20% of the electric power produced. With our open society and the need for short-term profitability, we should be concerned about our inability to plan for the long-term future.

John Campbell's new book, "Collapse of an Industry—Nuclear Power and Contradictions of U.S. Policy" (Cornell

Correction

- July 24: The cover identification was omitted. The photo, furnished by Du Pont, shows a worker testing a CFC alternative for cleaning electronic circuit boards.

Plastic composites use slows in 1989

The performance of the U.S. plastic composites industry has leveled off in 1989, according to figures compiled by the Composites Institute of the Society of the Plastics Industry. Shipments for the year are projected to increase only 0.3% over 1988 levels. Total shipments are estimated to reach slightly more than 2.66 billion lb for the year. This represents a significant change in the overall growth of the composites market as compared with 1988. In 1988, shipments increased overall nearly 5% over the previous year.

Polymer-based composite materials include reinforced thermoplastic and thermoset resins, reinforcements, and fillers used in a wide variety of applications. The transportation industry is the largest consumer of composites, representing 26% of the total market, yet shipments to the transportation industry will increase only 1.3% to 704 million lb in 1989. It is estimated that, later this year, commercial production by General Motors of a composite-based vehicle will add another 75 million lb per year to transportation industry figures.

The second largest composites market, at almost 19%, is the construction industry. This market remains steady with annual shipments of 495 million lb in 1988 and 1989, reflecting in part the poor performance in housing markets. The marine industry is another large market that accounted for 16% or 433 million lb per year in 1989, a 4.3% drop from 1988 levels. Shipments to the marine industry are showing the largest decrease of any of the nine market sectors. This is in contrast to 1988 when shipments were up nearly 10%. However, the drop in shipments to the marine industry is not being viewed as a trend and shipments are expected to pick up again in 1990.

A few markets, such as the aerospace and military, appliance and business equipment, and electrical and electronics markets, are looking stronger in 1989. Together these markets account for about 16% of the total market share, or about 429 million lb in 1989. Composite materials, because of their lightweight and high-strength characteristics, are finding increased application in armored military vehicles, ships, and commercial and military aircraft. Shipments to the aerospace and military market are showing the largest gain of 4.3%, reaching 41.1 million lb in 1989.

The appliance and business equipment, and electrical and electronics markets show the next largest gains of 2.5% and 2.2%, respectively. The electronics market uses 235 million lb in fabricating three-dimensional circuit boards that allow for the miniaturization of electronic components and in new chip encapsulation techniques. The corrosion-resistant equipment and consumer products markets are showing growth levels around 1.0% in 1989, to 351 million lb and 171 million lb, respectively. Composites use in corrosion resistance materials are expected to increase.

Ann Thayer

Aerospace uses of composites show most growth

Millions of lb	1989[a]	1988	1987	Change 1988–89
Aerospace and military	41.1	39.4	36.4	4.3%
Appliances and business	153.3	149.6	140.5	2.5
Construction	495.4	495.4	506.0	0
Consumer products	170.9	168.9	166.5	1.2
Corrosion-resistant equipment	350.8	348.7	329.0	1.0
Electrical and electronics	234.8	229.8	214.0	2.2
Marine	432.8	452.2	412.6	−4.3
Transportation	703.6	694.8	656.0	1.3
Other	82.2	79.5	75.3	3.4
TOTAL	**2664.9**	**2658.3**	**2536.3**	**0.3%**

a Based on six-month estimates and projections for the remainder of the year.
Source: Composites Institute, Society of the Plastics Industry

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CHEMICAL & ENGINEERING NEWS

National Chemistry Week aims to boost chemistry's image Page 44

FINAL PROGRAM PACIFICHEM '89 in Honolulu Page 53

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Stock ownership plans gain favor with companies, employees

Page 9

CHEMICAL & ENGINEERING
NEWS

Volume 67, Number 40
CENEAR 67 (40) 1–136
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OCTOBER 2, 1989

News of the Week

- **Despite lawsuit, plans proceed for Oct. 12 launch of Galileo spacecraft mission to Jupiter.** Page 4
- **Canadian biotechnology company, Connaught Biosciences, accepts takeover offer from Institut Merieux, a French biologicals firm.** Page 5
- **Satellite measurements indicate rapid ozone destruction above Antarctica.** Page 5
- **U.S.-U.S.S.R. accelerate efforts to spur chemical arms negotiations.** Page 6
- **Materials scientists and engineers seek more public, political backing for their field.** Page 6

Cover: Photo by Jon Feingersh/
Uniphoto Picture Agency

Letters 2

Concentrates
Business 7
Government 14
Science/Technology 18

The Departments
Books 39
Meetings 135
Newscripts 136

Business

Dow remains committed to petrochemicals despite its increased stake in consumer products and specialties. **Page 13**

Government

International gathering in Geneva aims for agreement on mechanisms for coping with global climate change; study concludes research experience to date is sufficient for scientists to make safe decisions regarding field tests using gene-altered organisms; Superfund operation reported to be hampered by built-in disincentives. **Page 15**

Science/Technology

From the Miami Beach meeting: Greater participation by chemists and drug companies sought in finding new medications to curb drug addiction; Merck Index marks its centennial; academic/regulatory science bridging programs urged; new developments in controlled-release fertilizers; research seeks to clarify structure of coal; electron-beam system shows promise for treating wastewater; designing new fuels for hypersonic aircraft focus of major effort; quartz crystal microbalance benefits surface chemistry studies; ultrafast chemistry probed; and end uses increasing for high-tech geotextiles. **Page 19**

ACS News

Council adopts three petitions, acts on other matters at Miami Beach meeting; plans are solidifying around the nation for National Chemistry Week. **Page 41**

Awards

ACS winners: Jurs, Karger, Knox, Laudise, Liebermann, McConnell, Merrifield, and Meyer. **Page 48**

Final Program

Program for PACIFICHEM '89 in Honolulu, Dec. 17-22, includes listing of technical papers, general events, registration form. **Page 53**

Cover Story

Employee stock ownership plans, advantageous to the employer as well as the worker, are drawing a lot more attention among companies, including several chemical makers. Page 9

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LETTERS

Help for meeting expenses

SIR: I read with interest Raymond Seymour's letter on taxed meeting expenses (C&EN, July 24, page 3). I, too, am an underfunded faculty member. I have been audited twice in the past few years, and had no difficulty defending the deduction for expenses for travel to ACS and other meetings to serve on committees, give papers, chair sessions, or just attend papers.

The Internal Revenue Service looks for a contemporaneous record of expenses including date, location, purpose, item, and amount. A printout from a credit card does not provide all of these, nor does it prove that you paid the bill. It is also helpful to request funds from your department; even a rejection or $10 assistance provides a record that your supervisor approved your professional need to attend, but could not provide funds.

If you do not request assistance, the deduction may be disallowed, because IRS may claim that you could have been reimbursed, and you have no proof to the contrary. I am not a tax expert, but I am convinced there is no need for panic. I recommend an annual publication—"Tax Guide for College Teachers"—for further advice about record keeping.

Linda M. Sweeting
Towson State University

Genetic screening and ethics

SIR: The excellent article on genetic screening (C&EN, Aug. 7, page 10) stresses the urgent need for society to develop some rational policies for dealing with the numerous ethical questions we can already foresee. However, extrapolating even further, I foresee a much greater question of ethics with the potential for destroying the basis of our society.

If we trace the progress made over the past 10 or 20 years in the understanding, at a molecular level, of the functioning of life, then it seems to me a not too improbable extrapolation that we will "explain" all of life in terms of chemical (biochemical?) reactions and the laws (of thermodynamics) that govern them. Any individual action will then be seen not as one of free choice but rather the inevitable result of the interaction of current, external stimuli with the contents of the individuals' memory banks.

What does this do to our view of individual responsibility? I shudder to think, and I see no escape. Science fiction? Look back at the progress I referred to above and contemplate how much chemical control we are able to exert, even now, over physical, mental, and emotional bodily functions.

Our struggle with ethics hasn't started yet.

Brian Kipling
Calgary, Alberta

Patent protection

SIR: I write to comment on an obviously unintended inference that might be drawn from one of the comments in William Lovell's letter (C&EN, Aug. 14, page 3). The single largest misconception that the public has about patents is that they directly protect the owner's right to practice his or her invention. Instead, the patent gives its owner the right to exclude third parties from using his or her invention. (This right is analogous to the right of a homeowner to exclude third parties from trespassing on his property.)

The patent right of exclusion can, of course, be extremely valuable where others will pay high royalties for a license, or where, because of the patent and the absence of relevant third-party patents, the owner of the patent in question is the only one who can lawfully practice an important invention.

But the only protection of "the right to practice an invention" offered by a patent is the indirect protection that it affords by preventing or limiting third parties from obtaining patents on their later inventions directed to the same or similar idea.

Nathaniel D. Kramer
Sprung Horn Kramer & Woods
New York City

Safety of nuclear power

SIR: In the book review on "The Social Impact of the Chernobyl Disaster" by David R. Marples (C&EN, July 17, page 38), the reviewer, C. P. Wolf, included a serious error by implying that the Hanford N reactor design is similar to that of the Chernobyl RBMK-type reactor from the standpoint of safety. We are not certain that this error is introduced by the reviewer, or was also stated by the book's author.

The Hanford N reactor, like the RBMK, is light-water-cooled and has a graphite moderator with its fuel contained in pressure tubes. However, that is where the similarity with the Chernobyl reactor stops. Unlike the RBMK reac-

More Companies Offer Employee Stock Ownership Plans

Benefit plans that put shares in employees' hands provide worker incentive, can give companies tax advantage and protection against takeovers

Ann M. Thayer,
C&EN Northeast News Bureau

Employee stock ownership plans (ESOPs) are not new. Yet they have been attracting a lot of attention in the past year. Several companies in the chemical industry are among those recently setting up such plans. It is estimated that by the end of this year more than 10 million employees will be covered by one form or another of an ESOP. Although that figure is more than triple what it was 10 years ago, the increase in borrowing by companies to finance these plans is even more dramatic.

Borrowing has gone from a level of $1.2 billion in 1986 to $5.5 billion in 1987 to $6.5 billion in 1988, and may exceed $20 billion in 1989, says the National Center for Employee Ownership (NCEO), a nonprofit research organization located in Oakland, Calif. In 1989, nearly 85% of the money loaned will be to larger, public companies that account for only 10% of all plans, says Gianna Durso, project manager at NCEO.

Some companies in the chemical industry, such as Aristech Chemical, Betz Laboratories, FMC, Olin, and PPG Industries, have plans that are tailored to their specific interests and outlook. But the reasons behind the boom in ESOPs, and what make them attractive, generally are the same for most companies. These include corporate tax advantages, an opportunity to introduce a new form of employee benefit, and a degree of protection from hostile takeovers.

An ESOP has several basic features. Most public companies have leveraged plans. A company establishes a trust, which then borrows money to purchase shares of company stock. The loan is usually guaranteed by the company. Cash received from the sale of stock to the trust is available for corporate purposes. Meanwhile, the company, through dividend payments and contributions to the trust, helps to repay the loan. Employees are allocated shares, the number of which is typically based on a relative salary scale or company matches in employee savings plans.

An ESOP also provides a company with some significant benefits. Payments, of an amount up to 25% of the payroll of ESOP participants, made to the trust and used to pay off both the interest and principal on the loan are tax deductible. Dividend payments are also deductible if used to pay down the debt or passed on to employees. In addition, half of the interest income for the lender in a leveraged ESOP is tax deductible. Thus resulting loan rates have been about 90% of prime, or sometimes less, according to NCEO.

Call: tied to company performance

The high levels of borrowing, in light of the tax advantages, have attracted the attention of the federal government. "The U.S. General Accounting Office has estimated that ESOP borrowing will cost the government about $8 billion in lost revenue over the next five years," says Durso, "and Congress is concerned about that."

The purpose of an ESOP, as written into the legislation, is to increase and broaden employee ownership in U.S. business, she explains. However, because of the tax advantages over other employee benefits programs, some companies are replacing existing benefits with ESOPs. Although employees may not lose anything by this, she adds, Congress doesn't necessarily want taxpayers footing the bill, while companies are spending less to provide the same level of benefits.

This led to the introduction of a bill this summer by the House Ways & Means Committee to cut the interest exclusion for lenders. The proposed legislation was intended to cut the borrowing but had little effect on the number of ESOP announcements. Another proposal was then added to the legislation cutting the allowed deduction on dividends.

"That seems to have had the desired effect," says Durso. Although the legislation in the House has not yet been passed, there has been a dramatic drop-off in the number of announcements. Bills also have been introduced in the Senate to limit the interest exclusion on plans with less than 20 or 30% ownership, which is consistent with ownership levels in many private companies.

For public companies, NCEO estimates that the average amount of stock in employee ownership plans ranges from 5 to 15%. The level of ownership has important consequences in defending against a takeover. The Delaware statute, under which many companies are incorporated, stipulates the percentage of shares that must be voted to approve a takeover.

"In order to approve an acquisition, you need the affirmative vote of 85% of nonaligned shares," says Lilli Gordon, director of research at Analysis Group, an economic and financial consulting firm in Belmont, Mass. "So if you have 15% of nonaligned shares in friendly hands, that basically gives you veto power." But only a fraction of the plans, about 20%, are of sufficient size to have control, she notes. NCEO reports that as many as a third of the plans in public companies are put in as takeover defenses.

Gordon calls such plans "anticipatory takeover defenses" that are put into effect before any takeover move is made. "Poison pills were too transparent," she says. (Poison pills are shareholder rights plans that result in premium share prices.) "Companies tried to uphold their poison pills and it was clear that their only purpose was to deter a hostile takeover." It is generally believed that the courts will uphold the votes of shares held in an ESOP because of the precedent set in a case surrounding the attempted takeover of Polaroid by Shamrock Holdings.

Polaroid instituted an ESOP, with enough shares to repel a takeover, a few weeks before the company was approached. In a suit brought by Shamrock, the Delaware Court upheld the ESOP as an employee benefit that the company had been considering for some time, rather than simply a takeover repellent. Observers believe that companies will use the Polaroid ESOP as a guide, but suggest that, to be upheld in the courts, the plans must be in place as employee benefits prior to any takeover attempt.

Aristech Chemical, in business for just under three years, believes that it is good business to align the interests of its employees with those of its shareholders through two ESOPs, says J. Harry Varner of investor relations. During the past six months, however, Jon M. Huntsman of Huntsman Chemical has acquired more than 7% of Aristech's stock and has expressed an interest in the company (C&EN, June 12, page 7). Slightly more than 16% of Aristech's outstanding shares are held by the two plans.

One Aristech ESOP contains 3.6 million shares of common stock financed under a 10-year variable rate loan of $72.9 million. The second contains $60 million worth of a new issue of voting preferred shares, leveraged over 15 years, convertible to 2 million shares of common stock. The plans operate as most plans do in terms of loan repayments, allocation of shares, eligible employees, and voting and dividend rights.

As company contributions to the trust are used to service the loans under a set amortization schedule, those shares paid off are allocated to employees. The percentage of shares allocated to an employee's account is equal to the percentage an individual's salary represents in the total payroll of covered employees. The shares on account, or their cash value, become the property of an employee upon retirement or leaving the company.

The two plans differ only slightly since they are based on different types of stock. For the common shares, an employee receives the current market value when cashing out of the plan, whereas the preferred shares have a guaranteed value. Dividends on preferred shares are fixed and are used in part to pay down the debt. Dividends on the common shares can be used in the same way, passed through to employees, or used to purchase more shares.

Voting rights to allocated shares are given to the employees. And, as in the Polaroid plan, the shares remaining in trust are voted by a trustee, usually a financial institution, in the same proportion that the employees voted. This is a commonly used means of voting the shares. Other possibilities include voting all the shares in trust as the majority votes, or voting them independently. Exactly how the shares in trust are voted has the potential of becoming an issue, especially in a takeover.

For shares to be considered unaligned in an acquisition, employees must be allowed to vote their shares confidentially. "A company has to assume that its employees are going to vote with it, which

Stock plans growing in chemical companies

Several companies in the chemical industry have established employee stock ownership plans (ESOPs) in the past two years. Most plans are leveraged with a trust established to borrow money and to purchase shares of stock from the company. For the five companies whose plans are summarized below, this debt totals more than $800 million.

Company	Effective plan date	Type of stock	Number of shares (millions)	% of total	Plan debt ($ million)
Aristech	1/88	Common	3.6	10.4%	$ 72.9
	1/89	Convertible preferred	(2.0 common)	5.8	60.0
Betz Laboratories	6/89	Convertible preferred	0.5 (1.38 common)	9.0	100.0
FMC Corp.[a]	4/89	Convertible preferred (nonvoting)	na	na	300.0
Olin Corp.[b]	7/89	Convertible preferred	1.4	7.0[c]	100.0
PPG Industries[b]	1/89	Common	6.0	5.5[d]	250.0

a Plan announced but not in place pending federal tax legislation on ESOPs. Will replace savings plan with 38% of outstanding shares. b ESOP formed to provide future contributions to existing savings plan. Level of company match to employee savings based on annual return on equity. c Shares in ESOP and savings plan total about 24%. d Shares in ESOP and savings plan total about 14%. na = not available.

isn't always the case," says Durso. "Employees will naturally take employment security and other factors into account when voting their shares." A letter written by the Department of Labor to Polaroid called into question whether the voting rule allowed the trustee to fulfill its fiduciary duty.

FMC created an ESOP in April that essentially avoids this problem. The plan is based on a new series of nonvoting, nondilutive convertible preferred stock to be financed through a $300 million loan. The stock is to be converted to common stock upon allocation to employee accounts, but the shares remaining in trust are nonvoting shares.

Citing the advantages of lower cost financing, the company plans to replace its existing 401K thrift plan with the ESOP. The 401K plan, in which 60% of a maximum of 5% of an employee's salary is matched by the company in common stock, currently holds 36% of FMC's 36 million outstanding shares. However, the company has delayed implementing the plan until the outcome of the proposed tax legislation is known.

Other companies have gone ahead with ESOPs either because the tax advantages are not a major factor or because there is some hope that plans put in place now will be covered under the tax laws. In addition, once in place, it becomes much easier to expand an ESOP and add to the number of shares owned by employees. Betz Laboratories instituted an ESOP with 9% of its outstanding shares in late June as a supplement to its retirement plan and to encourage employee ownership in the company.

The ESOP includes the sale of half a million shares of convertible preferred stock to a trust. A $100 million loan for the purchase of the shares is to be paid off on a 20-year amortization schedule. R. Dale Voncanon, vice president of finance at Betz, indicated that by using preferred stock in the ESOP the company can set a higher dividend rate than on the common stock, and therefore get a higher tax deduction. At a point where the dividend on the common stock exceeds that of the preferred, it makes sense for the trust to convert the shares into 1.38 million common shares.

Campbell: improve return on equity

Whereas many plans, such as Aristech's, are nonparticipatory, PPG Industries has made its ESOP part of an existing employee savings plan. The company matches up to 6% of an employee's salary in PPG stock on a variable scale that ties the plan to company performance. "The match increases from a minimum of 50% of 6%, or 3%, to a maximum of 100% of 6% as the company's return on equity increases from about 15% to 22%," explains Lawrence M. Call, treasurer of PPG. Return on equity is the ratio of a company's net income to its net worth.

PPG contributes shares from a leveraged ESOP of 6 million shares of common stock. "In simple terms," he says, "we have essentially prefunded the employer's contributions to the savings plan." The PPG savings plan has been in place many years as an employee benefit, he explains. "The employees who are participants in the savings plan did not see anything happen except that we told them that we had changed the savings plan to an ESOP. The risks and rewards are identical."

One change that had to be made was to give employees the option to receive dividends or have the dividends reinvested for additional shares. Dividends can be viewed as a short-term reward for employees in plans that are essentially long-term benefits, since the actual shares become the property of an employee only upon leaving the company or retirement. With other bonus and profit-sharing programs, PPG does not consider its ESOP an incentive program except to the extent that it encourages investment, points out Call.

Olin Corp., with a plan similar to that of PPG's, is focusing more on having employee ownership work as an incentive to improve company performance. "Olin is striving to improve its return on equity and to improve the value that it returns to shareholders," says Michael E. Campbell, vice president, human resources. "Our goal is to achieve, on a reasonably consistent basis by the early 1990s, a 20% or better return on equity."

In trying to enhance its existing employee savings plan, the company decided to increase the company match of 50% of the first 6% of an employee's salary when its return on equity goes above 14%. For every point above 14%, the company match increases 5%, so at 17%, which is the goal for 1989, the match would be 65%. The company has put 1.4 million shares, or about 7% of outstanding shares, into an ESOP for future contributions. The proceeds will be used to repurchase its common shares.

Through the existing savings plan, employees already own about 17% of the company's shares. "We think now by marrying the concept of improved return on equity [to the bonus stock match], we will increase the employee commitment to improved performance." Campbell stresses that the plan more closely aligns employees' interests with those of the company's shareholders. "Employees have the greatest impact on the performance of the company and are able to fully share in the benefits of that improved performance, both as employees and as owners of the company."

It can be difficult for an individual to directly affect return on equity, admits Campbell. "However, all of us working together in terms of cost savings, in improving quality to become a preferred supplier and therefore have improved sales and margins, will impact return on

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equity." Research shows, says Durso of NCEO, that combining employee ownership with a participative style of management can help a company grow 8 to 11% faster per year than competitors. "The ownership provides the incentive, and the participative management provides the means for getting employees involved," she says, However, NCEO stresses that both are needed to have an effect.

"There is a perception that the driving force in ESOPs is financial in nature," says Campbell of Olin. "Obviously the financial implications were carefully considered but, if you are just driven by that, you may save money in the short term but it's not going to be an effective tool for improvement over the longer term." Olin boasts 80% overall participation in its savings plan.

The plans fall under the Employee Retirement Income Security Act (ERISA), which governs employee benefits. ERISA requires that the plans allow for equitable participation among employees with union employees allowed to bargain into the plans. The plans are considered long-term benefits and there is usually a vesting period of five to seven years. At the age of 55, an employee can have access to his or her shares in order to diversify the account. Another way to ensure employees of some downside protection, especially when the ESOP is used as a retirement plan, is to guarantee a minimum stock value.

Although employees can share in the growth of companies, there is also a downside with benefits tied to stock prices. Most plans, except Aristech's preferred stock plan, are supplements to, or restructurings of, existing retirement plans or savings plans and present little risk or require few concessions on the part of employees. It is still too early to know how successful the plans will be as employee benefits or whether there will be an impact on measures such as return on equity. However, observers believe that the restructuring of benefits will continue as costs of benefits increase and companies are able to take advantage of the tax benefits and flexibility offered through capital accumulation plans such as ESOPs. □

International Gathering Aims for Pact on Climate Change Problem

More than 40 national groups meet in Geneva to thrash out multilateral limits for global change; situations of Third World nations given emphasis

Representatives of more than 40 countries are meeting in Geneva this week to devise possible mechanisms for coping with global climate change. The effort is a first step toward negotiating an international agreement on climate warming, says Frederick M. Bernthal an assistant secretary in the State Department.

"Global climate change could be the dominant foreign policy issue of the next century," Bernthal told a recent conference in Washington, D.C., on global-change decision-making. He stressed that any attempts to limit the emissions of greenhouse gases that lead to climate warming must be international if they are to have a significant impact. "It's an absolute necessity that developing countries be brought along in the process," he says.

The U.S. strategy of working toward multinational solutions is firmly supported by the Global Climate Coalition, a new Washington, D.C.-based business association. Yet some members of Congress and environmental groups are arguing that the U.S. should act unilaterally to curb its emissions of carbon dioxide, chlorofluorocarbons (CFCs), and other greenhouse gases.

This week's meeting in Geneva was convened by the Intergovernmental Panel on Climate Change (IPCC), an international forum established by the United Nations Environment Program and the World Meteorological Organization. As head of the U.S. delegation, Bernthal chairs IPCC's response strategies working group.

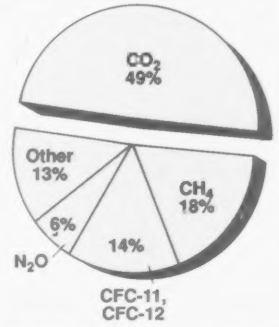
The response strategies group is one of three working groups set up when the IPCC met for the first time last November. The U.K. heads the working group charged with reviewing and assessing the science relevant to climate change, while the U.S.S.R. is chairing a group assessing the possible environmental and socioeconomic impacts of such change.

According to Bernthal, the response strategies group is analyzing both short- and long-term policies that could limit or mitigate global change. At this week's workshop, delegates are attempting to pull together a paper on mechanisms for implementing response strategies, especially in developing countries. One possibility under discussion is an international framework convention (agreement) on climate. The consensus paper will be presented at a plenary session to be held in February, perhaps in Washington.

Although the industrialized world now accounts for most carbon dioxide emissions, Bernthal says, that will change if the Third World is not helped to develop a different mix of energy sources. "If current trends continue," he says, "by the next century half of greenhouse gas emissions will be from the developing world. China plans to double its use of coal by 2000 and India plans to triple its use of coal."

Bernthal warns that developing countries will not support any climate convention if it means they must forgo the economic growth and increased energy use necessary to raise their standards of living. Therefore, he says, the issues of economic aid and technology development and transfer are crucial.

CO_2 is major contributor to greenhouse warming



Note: Estimated contributions to greenhouse warming calculated from atmospheric concentrations and radiative properties of gases.
Source: Environmental Protection Agency

The Administration's position is supported by the Global Climate Coalition which was organized earlier this year by the National Association of Manufacturers to provide a means for businesses to participate in studying climate change and in developing policy responses to the issue. Among the 50 some members are the Chemical Manufacturers Association, Dow Chemical Co., Du Pont, Pennwalt, the Society of the Plastics Industry, and Union Carbide Corp.

"We agree that climate change is a serious issue with enough scientific credibility to warrant the full attention of the business community," says coalition chairman Thomas G. Lambrix, who is director of government relations for Phillips Petroleum Co. Representatives of the coalition are attending the IPCC conference as nongovernmental observers.

Lambrix says that business must shoulder its share of the burden in reducing greenhouse gas emissions, by investing in cost-effective energy technologies, for example. But he also stresses that the federal government should carefully consider the cost of hasty unilateral actions that will be very expensive and perhaps ineffective.

But other voices are crying for faster action within the U.S. A slew of bills in Congress propose ways to limit global warming. One introduced by Rep. Claudine Schneider (R.-R.I.), for example, would require the U.S. to cut carbon dioxide emissions 20% by 2000.

And environmental groups also want the U.S. to develop its own domestic policy. Rafe Pomerance of the World Resources Institute, who also is attending the meeting in Geneva, says new statistics show that carbon dioxide emissions in the U.S. have been growing faster than those in the rest of the world for the past two years.

"We are the world's largest contributor and right now we don't have a policy on carbon dioxide emissions," Pomerance says. "We can't afford to wait. The quickest way to get multilateral agreement would be to lead by taking action within the U.S., not by increasing our carbon dioxide emissions."

The argument over unilateral versus multilateral action is unlikely to be settled anytime soon. In the meantime, Bernthal says, the U.S. is trying to encourage what he called "no regrets" strategies—that is, steps that make sense in and of themselves. Such strategies include increasing energy efficiency, reforestation in the industrialized and Third World, and eliminating CFCs.

The international community is already well on the road to a complete phaseout of CFCs, which not only catalyze ozone depletion but also account for a sizable portion of greenhouse warming (C&EN, July 24, page 7). Indeed, the process used to reach agreement on CFC use is often proposed as a model for handling climate warming issues.

But the CFC-agreement analogy only extends so far. "The issues of international equity, technology transfer, and economic development raised by CFCs will seem like child's play compared to those of climate warming," Bernthal warns.

Pamela Zurer

Tests of gene-altered organisms deemed safe

A study by the National Research Council of the risks involved in the release of genetically modified plants and microorganisms for scientifically controlled field tests finds there is little or nothing to worry about. It concludes that field-test experience to date gives scientists sufficient information to evaluate risks and make safe decisions.

The report divides the field-testing universe into plants and microorganisms. It does not cover larger animals or the use of genetically engineered organisms to produce other products. The report was done at the request of the interagency Biotechnology Science Coordinating Committee, which is composed of the five federal agencies most involved with biotechnology and genetic engineering.

The most significant contribution of the report is a detailed, tiered decision-making framework for the government offices to use when faced with approving a field experiment. According to chairman of the NRC committee Robert H. Burris, emeritus professor of biochemistry at the University of Wisconsin, Madison, use of the framework will make government testing decisions more consistent.

The framework has three major criteria. The most important factor is familiarity. This refers to how well researchers understand the plant or organisms and how much information has been gained from previous experiments. With regard to plants, familiarity is high because years of traditional crossbreeding research has provided much data. But familiarity with microorganisms is less because they have been studied for less time.

Confinement or control of the organism is the second major criteria on which the report says decisions should be based. Because modified plants are tested in small field plots, confining them is relatively easy, but control of microorganisms is more difficult. "Because less is known, the committee recommends that confinement and potential environmental effects be considered simultaneously," Burris says. "Confinement, in the case of microorganisms, might mean the presence of a temperature sensitive or other type of 'suicide gene' as these become practical and some other modification that would modify [the microorganism's] ecological niche."

Indeed, the third major criterion is concerned with the probable environmental effects should an introduced organism or genetic trait last longer than intended or spread away from the intended target. Questions that need to be asked include: What is the potential for persistence of the organism in the environment? Can it spread to nontarget environments? And, what is the chance of genetic exchange between the target and indigenous microorganisms?

Because the committee was limited to consideration of only research-scale field tests, much of what the report has to say has already been covered in other technical reviews. These include a white paper prepared by the National Academy of Sciences in 1987, a series of studies done by the Congressional Office of Technology Assessment, and a report issued earlier this year by the Ecological Society of America. In addition, many decisions have already been made about release of genetically engineered plants and microorganisms—about 80 field tests have already been approved by the Environmental Protection Agency and the Department of Agriculture.

Another big factor the committee did not consider is how individual states will react to field tests of altered organisms. At least 30 states have or are considering legislation to limit or control tests or the use of genetically engineered products. Burris contends, however, that "as experience builds with handling these organisms, and people see they can be properly regulated and that they cause no harm, they won't be as anxious or frightened of them."

The committee's report, "Field Testing of Genetically Modified Organisms: Framework for Decisions," is available for $19.95 from the National Academy Press, 2101 Constitution Ave., N.W., Washington, D.C. 20418.

David Hanson

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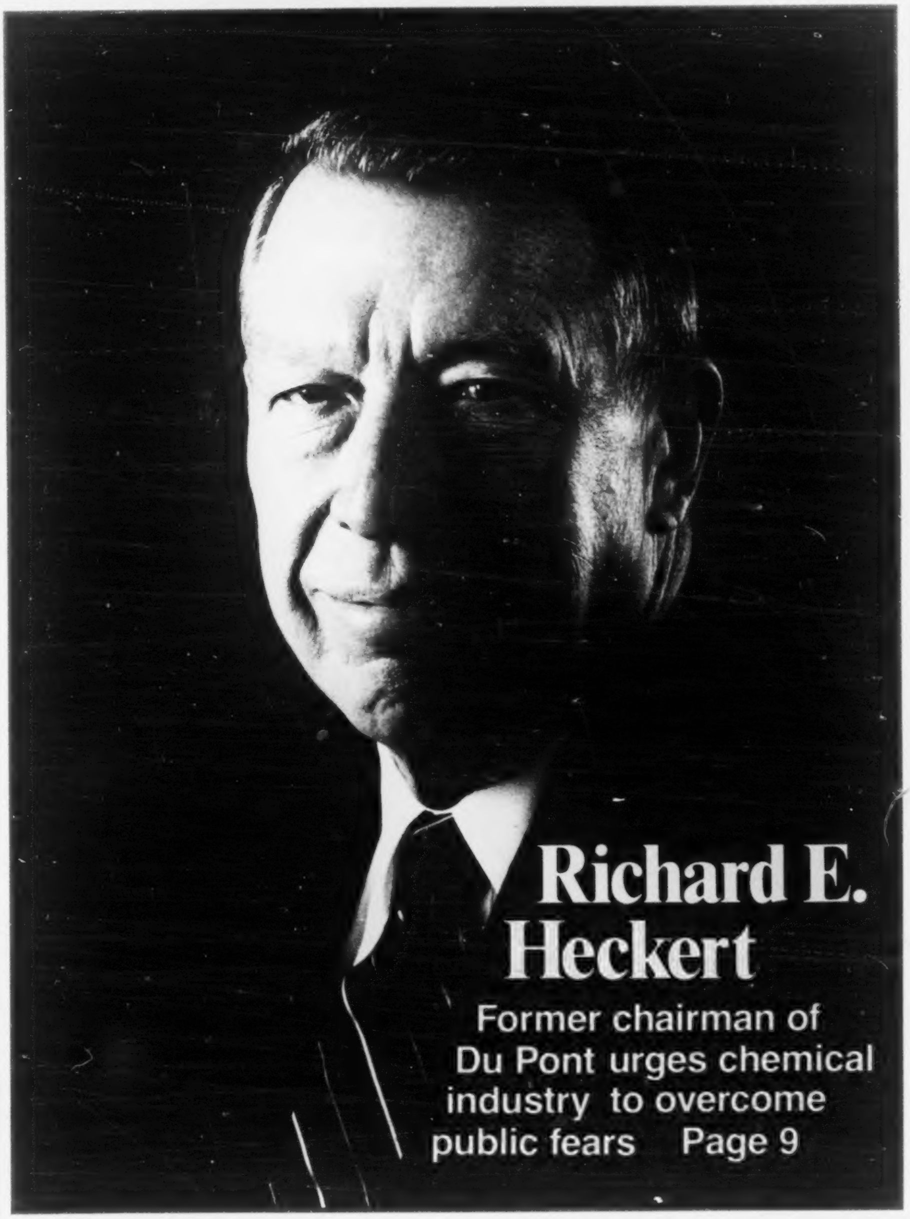

Richard E. Heckert

Former chairman of Du Pont urges chemical industry to overcome public fears Page 9

CHEMICAL & ENGINEERING
NEWS
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News of the Week

- **Three compounds that show promise to replace ozone-depleting chlorofluorocarbons have passed short-term toxicity tests.** Page 4
- **New ammonium perchlorate plant, replacing one destroyed last year by an explosion, will help mitigate what loomed as a critical supply situation for the oxidizer used in solid-fueled rockets.** Page 5
- **Human Genome Project got a lift from new findings reported at an international conference that appear to reinforce the belief among most researchers that the genome should be studied in its entirety rather than piecemeal.** Page 5
- **Merck and Du Pont will work together in the research and marketing of drugs for treating heart disease and hypertension.** Page 6
- **House agreement to set stricter auto tailpipe emissions standards removes the major hurdle to passage of amendments to the Clean Air Act.** Page 6

Cover: Photo courtesy of Du Pont

Letters 2

Concentrates
Business 7
Government 16
Science/Technology 20

The Departments
Meetings 32
Newscripts 48

Business

Western European petrochemical producers ponder environmental problems, business conditions at Monte Carlo meeting. **Page 13**

France's Atochem is boosting its polystyrene capacity substantially as the result of a spurt in demand for the plastic in Western Europe. **Page 14**

Government

Congress is again examining U.S. science policy and how best to reshape it to handle current science and technology issues. **Page 17**

Senate is pushing for more EPA regulation of pesticides and other chemicals used on foods. **Page 19**

Science/Technology

New applications of lasers add promising new approaches in analytical chemistry. **Page 21**

High-strength fiber is basis for a number of innovative protective clothing products. **Page 23**

Hybrid protein studies provide more insights on protein structure-function relationships. **Page 25**

Environmental expert systems gaining greater acceptability as decision-making tools. **Page 25**

Genetically engineered tomatoes, grown in the U.K., are being readied for taste trials. **Page 27**

Awards

ACS winners: Miller, Onak, Pimentel, Scheraga, Schultz, Scriven, and Speier. **Page 28**

Cover Story

SCI medalist Richard Heckert, former Du Pont chairman and chief executive officer, discusses public perception of chemistry, education, environment, U.S. competitiveness, other timely issues. **Page 9**

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LETTERS

CHEMICAL SAFETY

Liquid sulfur trioxide

SIR: The steadily increasing use of sulfur trioxide for commercial sulfonation prompts a caveat on its use in organic solvents. It is most often used as a vapor (boiling point 45 °C), but it is sometimes applied more conveniently as a solution in a chlorinated organic solvent. It is miscible in all proportions with many of these, with dichloromethane and 1,2-dichloroethane being favored for current commercial use because of cost and favorable physical properties.

These, and all other of the numerous chlorinated solvents tested to date, can react with SO_3 with varying degrees of ease—in some cases with explosive violence, and in most cases with the formation of toxic or irritating gases such as phosgene, which results from reaction with carbon tetrachloride. [These reactions are discussed in more detail in Gilbert, E. E., "Sulfonation and Related Reactions," Krieger Publishing Co., Melbourne, Fla., pages 4 and 371 (1977)].

It is therefore suggested that the following precautions be considered when using solutions of SO_3 in chlorinated solvents: (1) Maintain at room temperature or below; (2) Don't store—make only enough for immediate use; (3) Use unstabilized SO_3, since stabilizers promote reaction between the solvent and SO_3; (4) Avoid concentrated solutions (i.e., above about 25%); (5) Use fluorochloro solvents—they are more stable; (6) Add SO_3 and the organic compound concurrently to the solvent; (7) Use "fail-safe" equipment; (8) Consider the alternative use of liquid SO_2 (boiling point −10 °C)—an excellent, inexpensive solvent.

Everett E. Gilbert
Morristown, N.J.

Editor's note: Dichloromethane (methylene chloride) is considered by the American Conference of Governmental Industrial Hygienists to be a suspected human carcinogen. The need for proper ventilation and/or respiratory protection in working with liquid SO_3 and SO_2 should be noted.

Waste reduction

SIR: Mark Dorfman's letter (C&EN, Sept. 4, page 3) upholds the reduction of waste. Who could disagree with such obvious virtue?

Unfortunately, his statements are highly inaccurate. Most companies (including ours) are delighted with an annual payback of 50 cents for every dollar invested. If a return of "$50 for every dollar invested" (as he claims) were available, we'd be trampled in the rush to invest. We would not need a government edict.

Perhaps an act of Congress is needed, because much waste recycling is prevented by government action.

Two examples come to mind immediately. First, factories are generally not allowed to burn alcohols as industrial boiler fuel; the same alcohols are acclaimed as the solution to air pollution problems. The regulations also forbid one to burn as boiler fuel the same hydrocarbons that are burned as automobile fuel.

These are deemed "nonstandard fuels" by current Environmental Protection Agency regulations. It is indeed legal to burn them, but only after investment in instrumentation and supervision which return 2 cents for each dollar committed.

Second, regulations severely limit the reuse of solvents by routine distillation. If a solvent is part of a process loop, it may be recovered and reused. If the same material is taken out of the loop and put into drums for later distillation and reuse, it can be deemed hazardous waste and therefore cannot be reused.

Meanwhile, more and more bills are proposed telling us to reduce waste. Will the right hand in EPA tell the left hand?

Seymour Mann
President, Aceto Corp.
Flushing, N.Y.

Change over stagnation

SIR: I thought C. Milliren's comments about the decline in U.S. patents were exceptional (C&EN, Aug. 28, page 2). I also think we are missing the boat on turning ideas into patents and then into products because so much of corporate effort is now being focused on the short term and not on the long term. Corporate attitude is primarily responsible for the kind or lack of research that is carried out. All eyes turn to the chief executive officer and his or her vision. The worker, after hearing the goals set forth, understands and then follows the directives. The visionary attitude can be conveyed as, "Ideas are a dime a dozen," or ordinator for Shell and director of Shell International Chemicals Co., is the sheer volume of R&D investment by Western European companies over the past five years. R&D spending of major chemical companies in Western Europe has risen to greater levels than in the U.S. or Japan, from below $3 billion in 1983 to nearly $6 billion last year.

Part of the R&D work in the future, conference attendees agreed, will have to be on environmental matters, which also was the theme of this year's EPCA conference. Herwig Hulpke, director of the environmental department at Bayer, pointed out that when a recent survey of young people aged 16 to 20 asked about political priorities to the year 2000, some 88% mentioned the environment first. "Things have changed drastically and very rapidly over the past few years," he said. "This is a very big issue in public opinion."

The conference allocated one morning's session to a debate between representatives of chemical producers from West Germany and the U.S., and environmentalists from the U.K. and Sweden. The debate was introduced by Tom Burke, chairman of Green Alliance, based in London.

He posed the question: "How does the chemical industry look to the outside world?" And he furnished the answer. "You didn't set out to become monolithic, secretive, indifferent, sometimes arrogant, always selfish, avoiding responsibilities, cosmeticizing problems, and reluctant to act. But you got there anyway. You live in a world of prejudice, and only confirming evidence counts. You can't blame environmentalists for these perceptions—you did it all yourselves," he added, citing a string of serious industrial accidents or tragedies.

In some areas, he pointed out, those perceptions are beginning to matter. For example, industry is finding it more difficult to acquire sites, there are higher regulatory hurdles, and there is difficulty in recruiting the best and brightest young people.

Among other things, Burke presented a short list of industrial do's and don't's. First, "Improve your environmental performance. That's the bottom line: Nothing will improve without that. You must treat the environment like any other capital asset," he said, requiring such attention to detail as personnel training, performance monitoring and audits, specified resources given to specific programs, and so on.

"Be open. Answer the questions before they're asked—it's not hard to anticipate what people are concerned about. Be seen to be trying. Let people know you are trying harder," he suggested. And just as important, "Don't fight battles you've lost. Get ahead of the wave."

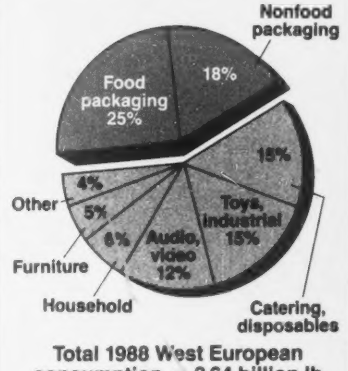
What not to do? "Do not expect quick results," he advised. "You didn't get where you are now overnight. And do not use the words 'emotional,' 'irrational,' or 'expensive'—they won't work."

Patricia Layman

Rising polystyrene use spurs Atochem moves

Atochem, the chemicals arm of the French Elf Aquitaine energy group, is boosting its polystyrene capacity more than 10% to 660 million lb per year. Its latest expansion is at the Stalybridge plant of Atochem U.K. Ltd., near Manchester, which late last month opened its third polystyrene line with a capacity of 120 million lb per year. The new line will replace an older, technically more

Packaging accounts for 43% of polystyrene use



Total 1988 West European consumption = 3.64 billion lb

Source: Atochem

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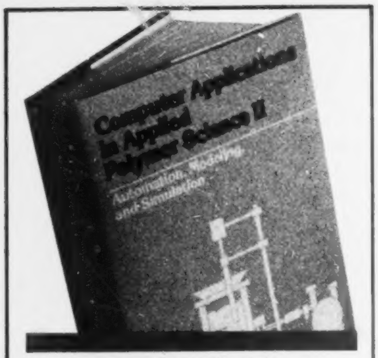

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limited plant of 55 million lb capacity, giving a net increase of 65 million lb per year, and raising the total polymerization capacity at Stalybridge to 176 million lb per year.

Atochem is making the addition as part of a modernization program that will affect its entire polystyrene capacity. The company got a major boost in 1987, when it acquired the polystryene operations of Arco Chemical at El Prat de Llobregat, near Barcelona, with a capacity of 132 million lb per year. Last year, it modernized its Gonfreville unit, near Le Havre, France, where it now has a capacity of 352 million lb per year.

Moreover, also this year and into next, the company will be boosting styrene capacity at Gonfreville, completing a new pilot plant at El Prat, and modernizing two compounding plants at El Prat and Stalybridge. Current compounding capacity is 77 million lb per year.

For Atochem, the polystyrene business is a good one. Current consumption of the polymer in Western Europe is about 3.64 billion lb, up from 2.87 billion lb in 1984, with much of the growth coming from a spurt in demand in the past two years. One of the major contributions to this spurt has been the growth in the new segment of packaging for compact discs, in the audio/video category, which accounted for only about 5%, or 138 million lb, of the polystyrene market in 1978. The category now accounts for 12% of consumption, or 437 million lb.

This year, "if the rate of increase of the first half of 1989 is maintained, it would be feasible to expect the ... growth rate to be 2 to 3%," said Alain Perret, director of the polystyrene business for Atochem, at the plant opening ceremonies.

However, he added, future growth will be more conservative. He predicted that demand for polystyrene in Western Europe will grow 1.5 to 2% per year, with exports growing at a faster rate. The rate of increase in demand in developing economies, he added, will be much quicker than in the three major producing areas of North America, Europe, and Japan.

Patricia Layman

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OCTOBER 16, 1989

CHEMICAL & ENGINEERING

NEWS

Rheumatoid Drugs

Better understanding of diseases opens way for new therapy

Page 37

CHEMICAL & ENGINEERING
NEWS

Volume 67, Number 42
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OCTOBER 16, 1989

News of the Week

- **For work in molecular biology, two U.S. scientists win Nobel Prize in Chemistry, and two others receive the medicine or physiology prize; two U.S. scientists and a West German earn physics prize for contributions to atomic precision spectroscopy.** **Page 6**
- **NSF to require that research proposals include a statement on how a project will contribute to the training of future scientists and engineers.** **Page 7**
- **Vietnamese scientists seeking to build ties with U.S. scientists.** **Page 8**
- **ICI sells over-the-counter drug business to Johnson & Johnson-Merck Consumer Pharmaceuticals, shifts focus of its U.S. drug business.** **Page 8**

Business

Chemical industry is becoming more global, but still has long way to go, executives conclude at Society of Chemical Industry meeting. **Page 15**

Government

Chemists are big part of FDA's new drug approval process; National Research Council calls for major boost in ag research funding; NIH and industry examine pitfalls to be avoided in collaborative efforts. **Page 19**

Science/Technology

Iowa tries to attract biotech firms using showcase presentation of university facilities and research; two new fibers challenge insulating properties of duck down; Wayne State University researchers reproduce evidence of superconductivity above 200 K; new way to synthesize high-tech crystalline solids; Japanese exhibit aims at improving public's image of chemistry. **Page 24**

Education

Gloomy assessment of U.S. science education was heard by academic/industrial group attending the annual meeting of the Council for Chemical Research. **Page 33**

ACS News

The society's Campaign for Chemistry receives $2.5 million donation from Mildred and Donald Othmer. **Page 72**

Awards

ACS winners: Tatlow, Thomas, Trost, Vogl, Weeks, Welch, and White. **Page 81**

Cover: X-ray of arthritic hand. Photo courtesy of Arthritis Foundation

Letters 4
Editor's Page 5

Concentrates

Business 11
Government 18
Science/Technology 23

The Departments

Software Database/Update 32
New Products 57
ACS Focus 71
Newscripts 100

Product Report

Understanding of the immune system and progress in the methods of biotechnology have brought chemists to the threshold of a new generation of compounds to treat rheumatoid disease. Page 37

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LETTERS

Origin of inventions

SIR: I agree completely with Charles Milliren (C&EN, Aug. 28, page 2) that present emphasis on the management track for young chemists and engineers denies them the intensive exposure and incubation in technology that they must have before they can make patentable inventions.

Milliren's letter was far too polite. During my career, management was ignorant technically, but willing to consider a development program, if properly presented, that might take as long as five years. The new graduate business school managers are taught to look out first for themselves, since only what is good for them is good for the corporation. What is good for them is this year's bottom line, and anything else be damned. They suffer from the delusion that inventions originate not in trained, experienced minds, but in a computer.

Only a terrible depression will rid us of these incompetents and bring us back to hard work and common sense.

George Karnofsky
Emeritus member
Pittsburgh, Pa.

Strategic Defense Initiative

SIR: I have a problem supporting the so-called Strategic Defense Initiative, or "Star Wars." Assume that two or more completely effective systems are developed, deployed, and forced into use by a hostile globe-traversing launch. Assume that all offensive missiles are successfully destroyed prior to reaching their targets. Would not some of them be hit by satellite-based defensive missiles during their rising trajectory and thus in some cases over their home territory? Would not some be destroyed during their high-altitude passage? And would not some finally be destroyed in the atmosphere close to their targets? Do not all these missiles, offensive and defensive both, contain fissionable and fusionable materials as well as high explosives and other forms of high energy? Would not mankind thus then have created an immense radioactive globe-girdling cloud of lethal fallout?

Perhaps these questions are too simplistic. However, I raise them for examination by our scientific community. Years ago I came to the conclusion that the weapons we used to end World War II should be the last mankind ever employs in anger.

What, then, can we do to continue our presently promising march for world peace? There are many definitely encouraging signs of progress. For instance, we are talking much more than we are fighting. This may be frustrating but it is rarely fatal.

William S. Hutchinson Jr.
Former Commander,
Joint Task Force Eight, Nuclear Testing

Preserve the name of chemists

SIR: The grievance regarding taxed meeting expenses by Raymond B. Seymour (C&EN, July 24, page 3) prompted me to write this letter.

For centuries, the reputation and salary compensation of chemists has always been beneath engineers, architects, and medical doctors, although chemistry is the oldest profession. This makes one wonder why, and I might have answers to this puzzle.

First, as a private consultant, I frequently have to compete with university professors and staff members for consulting and expert witness services. My fee is higher simply because I do not have a regular paycheck as they have, and, naturally, they will be retained as a consultant. This trend will force professional consulting chemists to get paid like a technician, and, thus, chemists work like slaves compared with other professionals.

Second, other degreed professionals, except chemists, have something to look forward to. For example, engineers want to acquire the title of professional engineer, accountants the title of Certified Public Accountant, and architects American Institute of Architects licensure. It is quite important in court that a chemist have certain recognition like the title of certified professional chemist. I sure hope that all chemists try to preserve the name of chemists.

Michael K. W. Li
President, Industrial Analytical Laboratory
Honolulu

Mousy odor of acetamide

SIR: For well over a century, acetamide has been described as associated with the odor of mice. Many of the authorities ascribe the mousy aroma to "an unknown impurity" and reassure the reader that pure acetamide without odor exists. I have prepared acetamide that remained free of mousy odor for several days. Do any of your readers know what impurities cause the mousy odor?

Frank Wagner
Corpus Christi, Tex.

Chemical Company Execs Chart Progress Toward Global Industry

Consensus at Society of Chemical Industry meeting is that industry still has long way to go; more restructuring, transnational mergers needed

Patricia L. Layman, C&EN London

Earlier this month in Venice, the chemical industry's top executives from Western Europe, plus a number of their counterparts from North America and Japan, compared notes and swapped information on the structural trends shaping an ever more global industry. This annual European meeting of the London-based Society of Chemical Industry—the continent's counterpart to the annual meeting of the Chemical Manufacturers Association at White Sulphur Springs—indicated that there is still work to be done within Western Europe to promote a transnational "European" chemical industry, rather than fragmented, smaller national industries.

How that work is accomplished will go a long way toward securing the place of the chemical industry in Europe in the international scene, where cross-cultural differences complicate the way to solving its problems. The problems are global: economic forces, environmental regulations and regulatory pressures, trade balances.

Moreover, an additional complication faces the chemical industry—probably the strongest manufacturing industry in Western Europe. How will it operate in the single internal market due to be in place by the end of 1992 in the European Community? Restructuring is one response. During the past year, for example, there have been several major signs of this activity progressing in Western Europe: the formation of the Italian chemical group, Enimont, for example, and the rumblings of restructuring ahead for the French chemical industry.

Popoff: growth is crucial question

In part, suggested Lorenzo A. Necci, chairman and chief executive officer of Enimont, the ramifications of the formation of a single internal market have made companies aware of the need to restructure and regroup forces within Europe, before tackling the world. "Although some weaker players have quit the game," he said, "we still have the remnants of the idea of petrochemicals as a national strategy." However, he added, "the fortress idea, with countries building walls around their chemical industry, has been a complete failure."

"If the idea of the multinational originated in the U.S.," he said, "I think that Europe is the source of the emerging transnational corporation. In fact, the engine of European integration is being powered by industry, and the chemical sector is playing a leading role."

But, Necci was asked, is not the creation earlier this year of Enimont from an amalgamation of EniChem and many of the chemical operations of Montedison—a creation he described as a "child of the market's needs and a defeat of the national mentality"—an indication that national thinking is still paramount? He acknowledged the apparent contradiction, but added, "First, you must clean up your house, to then deal with more strength and authority outside. Enimont is a beginning, in cooperation with Europe."

Nonetheless, as Robert Malpas, outgoing chairman of these autumn conferences and recently retired chairman of U.K.-based BP Chemicals, pointed out in his opening remarks, it is still far easier for a West European company to make a major merger or acquisition in the U.S. than in another country in Europe.

"There needs to be more transnational ownership; there needs to be more ease in transnational mergers and acquisitions," he argued. Indeed, this is an area in which companies, and commissioners within

Major transnational deals lagged in Western Europe in 1988

Mergers/acquisitions greater than $100 million	Value of deals, $ billions	Number of deals
Europe, within one country	$ 59.6	100
Transatlantic, Europe/ North America	52.6	101
Europe, cross-border	13.2	24
Europe/Asia	8.8	15
TOTAL EUROPEAN	$134.2	240
TOTAL U.S.	$202.5	323

Source: First Boston

the EC are still feeling their way toward encouraging world-scale competitive forces.

And, perhaps less obviously, one arena for such mergers and acquisitions could be Japan, suggested Shigekuni Kawamura, president of Tokyo-based Dainippon Ink & Chemicals.

Some Japanese chemical companies are beginning to make acquisitions outside their own country, although slowly. "We have little experience in selling outside Japan, little experience in production [outside Japan]. We would probably have to do joint ventures, pooling research, or have joint investment, but little in the way of outright takeovers," he said. "A hostile takeover would not work—the acquisition should be on a friendly basis, with negotiations." Those takeovers that do occur—such as that of Reichhold Chemicals and Sun Chemical by Dainippon—come about only when there have been long-standing relationships or working agreements. "We wouldn't buy unless we were sure we could find the right people to manage a U.S. or European company."

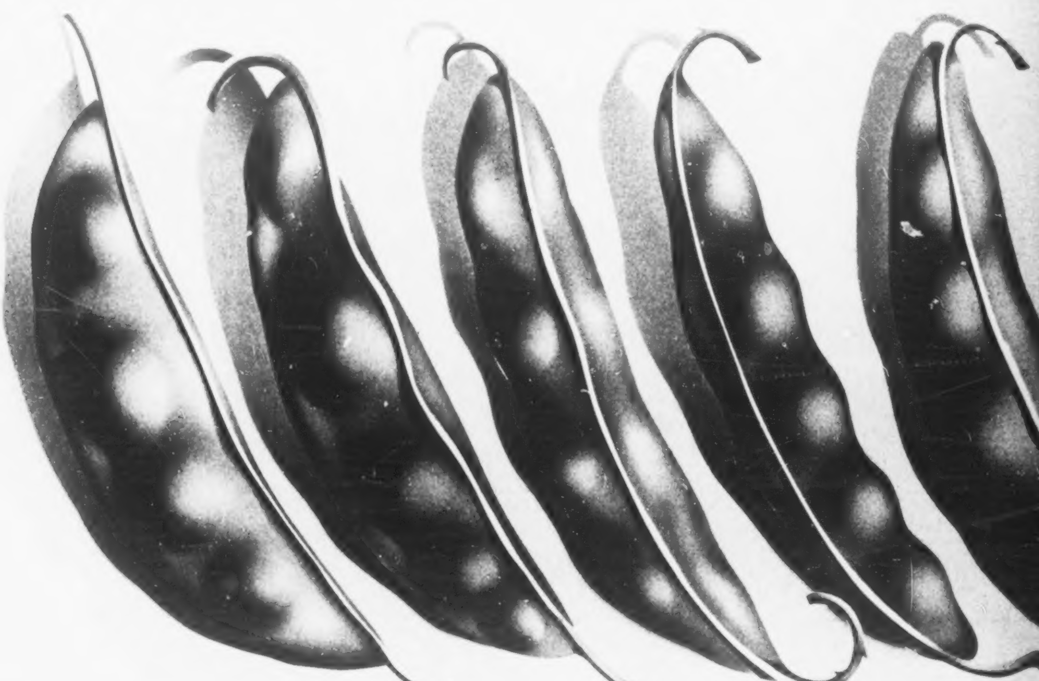
Moreover, Kawamura added, "it is easier for a non-Japanese company to buy a Japanese company: It is in your culture. For a Japanese company to buy a Japanese company is very difficult, because it is not in our culture."

Frank Popoff, president and chief executive officer of Dow Chemical, noted that "all manner of rationalizations, restructurings, mergers, acquisitions, joint ventures, and strategic alliances have had global reach and penetration as paramount motives. Counterproductive economic nationalism has been identified for what it is—an unsuccessful short-term defense against the power of global commerce."

A crucial question for the industry to ask, on a worldwide basis, he suggested, is the simple one: Is the chemical industry still a growth industry? Will new uses for polymers and plastics grow faster than environmentally driven reductions in demand? The same question, he added, also could be asked of chlorinated products, organic solvents, pesticides, and a variety of other chemicals. Will new applications grow fast enough to counterbalance the cuts in consumption that environmental pressures force?

"I suspect that few producers are discounting plastics growth by recycling rates and disuse initiatives," Popoff said.

As pressures against the chemical industry become more international, the need for industry to reflect the same international counterbalance becomes that much more important. At present, strong nationalistic forces still constrain corporate structure and ownership in the Western European countries. However, if further restructuring is to take place, legislation concerning



corporate structure and ownership will have to change significantly and quickly.

That, at least, was the prediction of Lord Francis A. Cockfield, a consultant on European affairs for Peat, Marwick McLintock, a London-based consulting firm. Cockfield, a vice president of the European Commission from 1985 to 1988, was the driving force and architect of the plan to bring about the single internal market.

According to Cockfield, the way the EC is developing—not only up to 1992, but beyond—"is of immense importance to industry and not least to the chemical industry because of its long tradition of international operation." This concern, he suggested, needs to be reflected at two levels: an industrywide level and an individual company level.

For the industry as a whole, he said, it is essential to watch, to understand, and, where necessary, to influence developments by contacts with the commission, with the European Parliament, and with the governments of the member states. This means, he added, with the commissioners directly involved in the pertinent areas and with the permanent employees in the bureaucracy of the commission.

For the individual company, no matter whether it is based in Europe, the U.S., or elsewhere, the question is one of developing a strategy to meet the opportunities and challenges not only of the internal market but also of the developments that will follow, Cockfield said. This, in turn, requires an in-depth knowledge of the community, of its policies, of community law, and particularly how that law is likely to develop.

One thing helping industry, he added, is the openness in the way the European Commission operates. In the development of the single internal market, for example, "at every stage, you could see the policy, and the way it was developing. There is not the secrecy of some member states' governments toward, for example, parliaments."

"1992 will inevitably require a restructuring of European industry," he pointed out. "We should take a positive attitude to measures that will assist with that."

How those measures develop will, of course, be crucial. But they cannot be tailored to cater to mere slogans or political posturing, Cockfield argued. "Simplistic beliefs in deregulation and free enterprise, for example, can lead to serious error. Excessive regulation may be bad, but equally excessive deregulation may be equally bad."

One of the most important things, he concluded, is the willingness of industry to temporarily assign "some of its best people to serve on committees to formulate standards, regulations, and so on. Ensure that your experts are there, when the spadework is being done." □

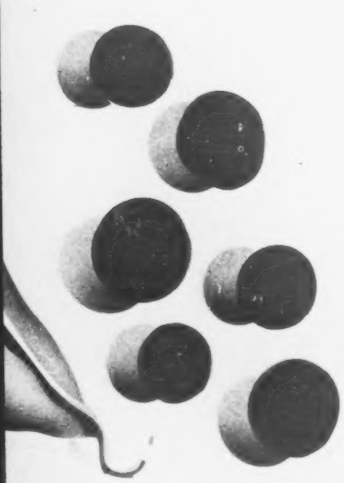


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Photo by Janet L. Stevenson-Kruzel

Better Understanding of Arthritis Leading to New Drugs To Treat It

Stephen C. Stinson,
C&EN Northeast News Bureau

Understanding of the immune system and progress in the methods of biotechnology have brought medicinal chemists to the threshold of a new generation of compounds to treat rheumatoid disease. As a product category, rheumatoid drugs are thus poised to generate increased sales and earnings for their developers owing to introduction of more effective, patent-protected biological and synthetic organic agents.

But drug companies face a treacherously shifting marketing climate today and into the 1990s in so-called nonsteroidal anti-inflammatory drugs (NSAIDs). These drugs are the most numerous, most widely used, and best selling of the category.

In one development, patents are expiring one after another, leading to competition of new generic versions against established branded drugs. Although doctors' and patients' confidences may have been shaken by recent reports of corruption and sloppy record keeping in tests and approvals of some generic drugs, no NSAID has been implicated.

In another development, the Food & Drug Administration has approved one popular NSAID, ibuprofen, to join aspirin in lower priced, over-the-counter marketing. The number of such OTC approvals is likely to increase in coming years. Though FDA will never approve OTC labels that claim effectiveness against such serious diseases as arthritis, doctors will surely guide their patients to them as first-line therapy as they appear together with instructions about how many pills comprise an anti-inflammatory dose.

The appearance of new NSAIDs and other categories of rheumatoid drugs makes it impossible to predict the marketing fortunes of older, potent, second-line drugs such as oral and injectable steroids, gold salts, penicillamine, hydroxychloroquine, sulfasalazine, azathioprine, methotrexate, and cyclophosphamide.

Rheumatoid diseases and drugs used to treat them

Rheumatoid diseases have a common feature in which the body mounts an immunologic attack against its own tissue. Examples are rheumatoid arthritis, systemic lupus erythematosus, Sjögren (SHOW-gren) syndrome, scleroderma, polymyositis, and dermatomyositis. They are also called collagen-vascular diseases and immune diseases of connective tissue.

But rheumatoid diseases are hard to define and difficult to diagnose. Doctors often simply have to "know them when they see them." Fifty years ago, physicians recognized only a handful. Today, they distinguish among more than 100 rheumatoid syndromes of various tissues. As the number grows and research continues, understanding and treatment will surely improve.

In addition to rheumatoid diseases, this report also covers osteoarthritis. Though not rheumatoid in nature, osteoarthritis can be as devastating as rheumatoid arthritis, and they share some features of pharmacotherapy.

Pain and tissue destruction of rheumatoid diseases result both from acute inflammation and from some unknown "rheumatoid process," which may be more than autoimmunologic attack. Thus there are two basic classes of drugs to treat them.

Nonsteroidal anti-inflammatory drugs (NSAIDs) alleviate pain, swelling, and tissue destruction of inflammation. NSAIDs take their name from oral steroids once favored to treat arthritis. As steroids fell from favor for this use, doctors turned to nonsteroidal drugs. The simplest NSAID is aspirin, though others include ibuprofen, naproxen, diclofenac, piroxicam, and sulindac.

The second class of "disease-modifying drugs" is a baffling collection of agents, some first used to treat other diseases, that seem to arrest the rheumatoid process in unknown ways. Examples are gold salts, penicillamine, hydroxychloroquine (an antimalarial), azathioprine (an immunosuppressant), and methotrexate and cyclophosphamide (anticancer drugs).

Many of these were developed to treat other diseases, and the reasons that they work against rheumatoid diseases are often unknown.

One analyst who has studied the marketing climate for prescription NSAIDs is Karl L. Habermas, of the investment research and management firm Sanford C. Bernstein & Co., New York City. Habermas estimates sales of $1.5 billion in 1989, growing at 11% per year to $2.3 billion in 1993.

To reach these figures, Habermas assumes that FDA will approve five new compounds during the period to join the 13 now available. At first sight, this total of 18 drugs of the same class may seem excessive, but there is a valid place for each in medical practice.

This is because each patient is an individual. Rheumatoid disease or osteoarthritis can be different in each person, and patients vary in susceptibility to such side effects as gastrointestinal upset and ulcers and kidney damage.

Thus doctors usually try high doses of aspirin first. If this is ineffective or not tolerated, the next step is a tour through the whole class of NSAIDs until an effective one is found. But this situation also means that the success of any new NSAID can depend not only on effectiveness and tolerability but also on the marketing prowess of its developer.

To Habermas, the most spectacular launch in recent years was that of Ciba-Geigy's Voltaren brand of diclofenac in 1988. Numbers of prescriptions peaked five months after introduction, which is very fast growth. Doctors will write 8.6 million prescriptions for it in 1989, Habermas says, which is 11.8% of the total and represents a huge success.

Among factors that Habermas cites that led to this success was mobilization of combined sales forces of both Ciba Pharmaceutical Co., Summit, N.J., and Geigy Pharmaceuticals, Ardsley, N.Y., with Voltaren as their number one priority. In addition, the company sponsored scholarly symposia and lectures about rheumatology, including papers on diclofenac, for two years before FDA approval. And the com-

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Arthritis Foundation photo

Lupus patients often develop cheek rash that confers wolflike appearance

pany placed advertising directed at consumers that included retired New York Yankees outfielder Mickey Mantle endorsing the drug.

Almost as successful was Upjohn Co.'s launch of Ansaid brand of flurbiprofen last January. Doctors will write 2.3 million prescriptions for this agent of the Kalamazoo, Mich., firm in 1989, Habermas estimates, which is 3.2% of the total.

The Upjohn sales force had to divide efforts among several products, he says, but the company is apparently successful in persuading doctors that Ansaid is a "new Motrin." Upjohn very successfully launched Motrin brand of ibuprofen 15 years ago on the strength of its low incidence of side effects. And Upjohn has agreed with Rorer Pharmaceuticals, Fort Washington, Pa., to market Ansaid jointly.

The next introduction to watch will be that of Relifex brand of nabumetone by SmithKline Beecham, Habermas says. FDA may approve it this year. The marketing effort will be a test of the new company formed by merger of Smith-

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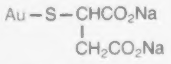
CIRCLE 30 ON READER SERVICE CARD

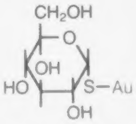
Disease-modifying drugs

Gold salts . . .

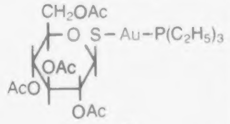


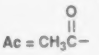
$$\mathrm{Au-S-\underset{\substack{|\\ CH_2CO_2Na}}{C}HCO_2Na}$$

Gold sodium thiomalate



Aurothioglucose

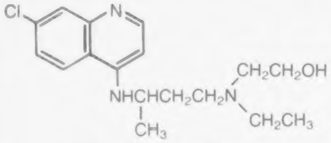




$$\mathrm{Ac = CH_3\overset{\substack{O\\ \|}}{C}-}$$

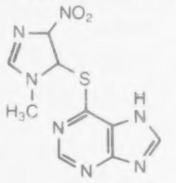
Auranofin

Antimalarials . . .



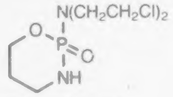
Hydroxychloroquine

Immunosuppressants . . .



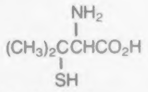
Azathioprine

Anticancer agents . . .



Cyclophosphamide

Others . . .



$$\mathrm{(CH_3)_2\overset{\substack{NH_2\\|}}{\underset{\substack{|\\SH}}{C}}CHCO_2H}$$

Penicillamine

Kline Beckman Corp., Philadelphia, and Beecham Group, London, last July.

Meanwhile on the over-the-counter front, Habermas predicts that Syntex Laboratories, Palo Alto, Calif., will soon apply for OTC approval of naproxen. Also, the newly founded joint venture Johnson & Johnson • Merck Consumer Pharmaceuticals Co. may decide to market OTC versions of Merck's diflunesal, indomethacin, and/or sulindac.

The NSAIDs themselves cata-

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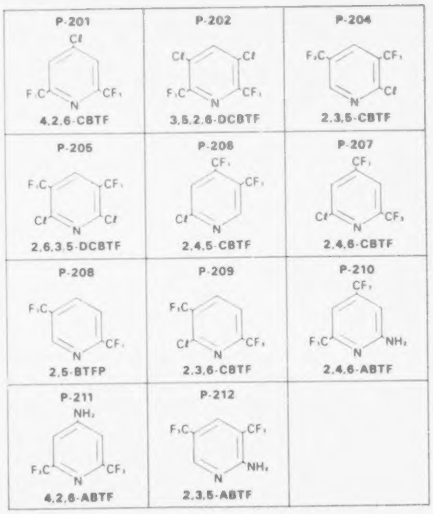

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pulted into prominence 20 years ago as a result of a hypothesis by medicinal chemist John R. Vane, now at Burroughs Wellcome in England. Vane suggested that aspirin reduced fever, swelling, and pain by inhibiting an enzyme then called prostaglandin synthetase.

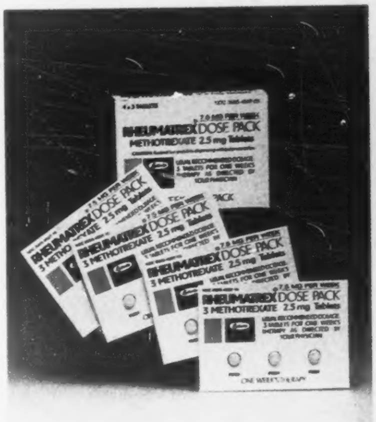
Such symptoms are caused in part by excess biosynthesis of prostaglandins. Prostaglandins are a series of about 20 oxygenated, unsaturated compounds with a 7-(2-octylcyclopentyl)heptanoic acid skeleton.

Synthesized and almost instantly degraded in every body tissue, prostaglandins are extremely potent regulators of a sweeping range of normal functions, including blood pressure and flow, blood platelet aggregation, labor in childbirth, and gastric acid secretion, in addition to pathological pain, fever, and inflammation. Vane's theory proved correct, and he shared the 1982 Nobel Prize in Physiology or Medicine with Sune Bergström and Bengt I. Samuelsson, of Karolinska Institute, Stockholm, who had isolated and studied a wide variety of prostaglandins and related compounds.

It is now known that the cascade of reactions that leads to biosynthesis of prostaglandins and many other compound types begins with liberation of such polyunsaturated fatty acids as arachidonic acid from disrupted membrane lipids, catalyzed by phospholipase A_2.

Among reactions that can occur next, cyclooxygenase catalyzes addition of molecular oxygen across conjugated double bonds to form cyclic prostaglandin endoperoxides such as prostaglandin G_2 (PGG_2). This can be converted to the endoperoxide PGH_2, which in turn leads to mediators of inflammation like PGE_2 and $PGF_{2\alpha}$.

Most NSAIDs known to date are inhibitors of cyclooxygenase. But individual NSAIDs differ in their acidity and ability to cross certain membrane lipid barriers. Thus an agent that works in one patient may be ineffective in another. And shutting down cyclooxygenase in one person's inflamed joint may or may not affect prostaglandin biosynthesis in other tissues.



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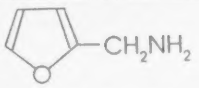
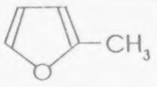
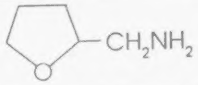
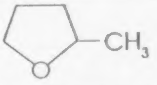
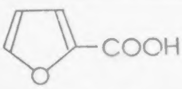
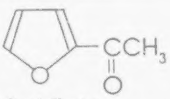

2-Furfurylamine

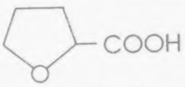

2-Methylfuran

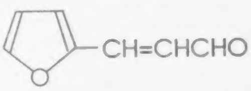

2-Tetrahydrofurfurylamine

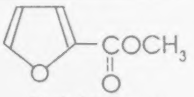

2-Methyltetrahydrofuran

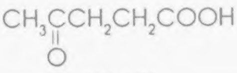

2-Furoic Acid


2-Acetylfuran

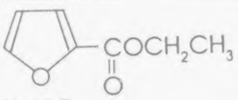

2-Tetrahydrofuroic Acid

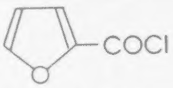

3-(2-Furyl) Acrolein


Methyl 2-Furoate


$CH_3\underset{\underset{O}{\|}}{C}CH_2CH_2COOH$

Levulinic Acid


Ethyl 2-Furoate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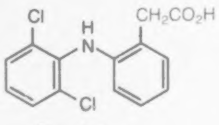
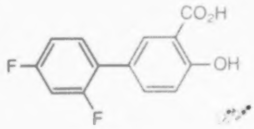
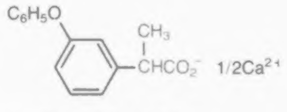
Individuality of patients and disease states requires a variety of anti-inflammatory drugs



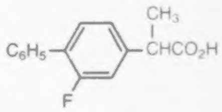
Diclofenac



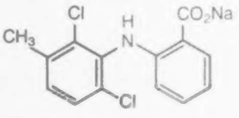
Diflunisal



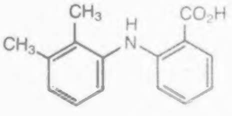
Fenoprofen calcium



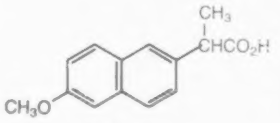
Flurbiprofen



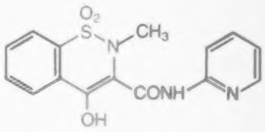
Meclofenamate sodium



Mefenamic acid



Naproxen

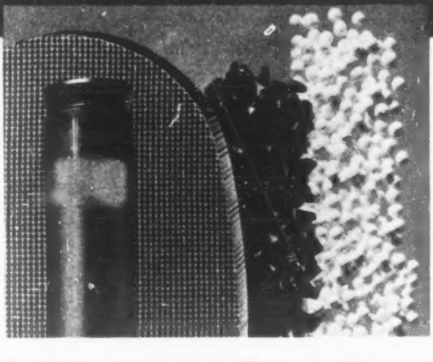


Piroxicam

Note: Groups of atoms in color are those that make each compound a member of its class.

prostaglandins suppress excessive gastric acid secretion and help maintain adequate blood flow in and sodium excretion from kidneys. If an NSAID also stops prostaglandin biosynthesis in stomach lining, gastric upset, bleeding, and/or ulceration may result. Ulceration may be insidious, remaining without symptoms until far advanced. And gastrointestinal hemorrhaging can cause death in the elderly.

Stoppage of prostaglandin biosynthesis in kidneys can lead to damage there or can accelerate damage



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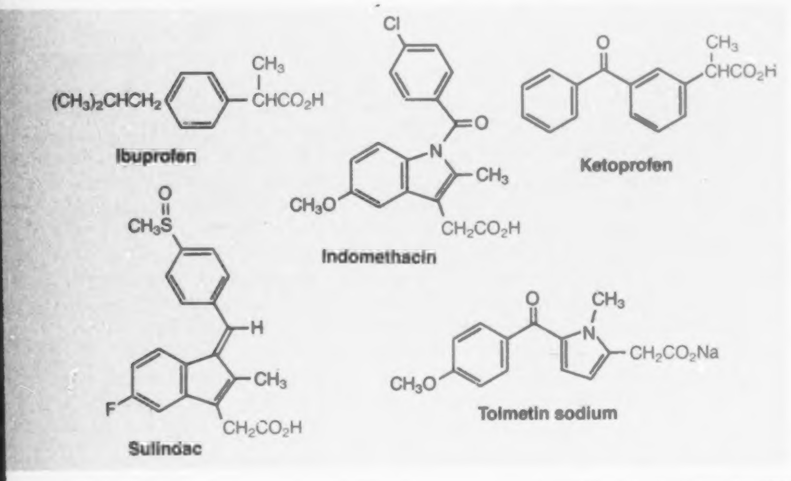


Ibuprofen

Indomethacin

Ketoprofen

Sulindac

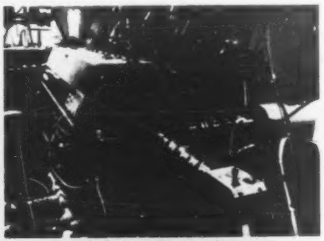
Tolmetin sodium

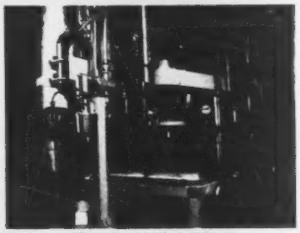
in kidneys that already are impaired. One rheumatoid disease in particular, systemic lupus erythematosus, often includes both an autoimmune attack on kidney connective tissue and arthritis. Thus NSAIDs must be prescribed cautiously for lupus patients.

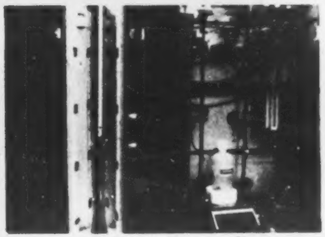
It is to prevent gastrointestinal side effects of NSAIDs that G. D. Searle & Co., Skokie, Ill., got FDA approval to market Cytotec brand of misoprostol. The compound is a 16-hydroxy-16-methyl analog of prostaglandin E_1, but lacks the hydroxyl of PGE_1 at C-15. The compound is absorbed into the bloodstream, from where it apparently replaces the prostaglandin in stomach tissue whose biosynthesis NSAIDs inhibit. Patients take a 200-µg tablet with each meal and at bedtime.

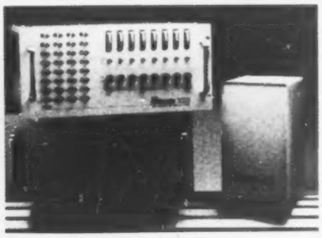
One side effect of Cytotec is bleeding in 40% of pregnant women and miscarriage in some. This is because one of the many normal functions of prostaglandins is to help begin labor at term. Thus Cytotec is contraindicated in pregnant women.

Because of side effects associated with blocking cyclooxygenase, and because prostaglandins are only a few mediators of the complex process of inflammation, medicinal chemists also have explored blocking 5-lipoxygenase. This enzyme also catalyzes reaction of polyunsaturated fatty acids with oxygen, but, in the case of arachidonic acid,









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to 5-hydroperoxyeicosatetraenoic acid. This compound is converted successively to five mediators of inflammation called leukotrienes A_4 through E_4.

It is against this backdrop that industry observers are watching the progress of tenidap through the approval process. Discovered in the research laboratories of Pfizer in Groton, Conn., the compound has entered Phase III testing (extensive clinical tests in humans). Bernstein's Habermas predicts approval may come between 1993 and 1995, and he has not included it in his market projections.

Tenidap appears to lower production of four different mediators of acute inflammation and perhaps of the enigmatic rheumatoid process itself. These are prostaglandins, leukotrienes, interleukin-1, and C-reactive protein. The six known interleukins are polypeptides secreted by various blood cell types that stimulate one another and cells of other tissues to mount the whole panoply of events of inflammation and destruction that comprises the immune response to antigens. C-reactive protein is one of the so-called acute phase proteins synthesized in the liver during flares of rheumatoid disease. Tenidap's ability to affect four markers of disease makes it the first of a new generation of therapy.

But for all the promise of tenidap, Michael J. Berendt of Pfizer almost takes it all away again as he cautions against reading too much into the evidence. Berendt, who directs Pfizer's department of immunology and infectious diseases at Groton, points out that these findings are only preliminary in an unfinished study in a small number of patients.

Tenidap almost certainly inhibits cyclooxygenase and therefore biosynthesis of prostaglandins in humans. It also blocks 5-lipoxygenase in vitro and decreases leukotriene activity in humans. But actual effect on 5-lipoxygenase in humans is unproven. And knowledge of leukotrienes is so sparse that it is unknown whether suppression of their biosynthesis will benefit rheumatoid patients.

The Pfizer agent seems to decrease concentrations of interleukin-1 in blood of a small number of rheumatoid arthritis patients. In these patients, the amount of messenger ribonucleic acid (mRNA) coding for interleukin-1 seems unaffected. Bererndt suggests that tenidap may affect processing of a 33,000-dalton precursor to the 17,000-dalton interleukin.

As for tenidap's suppression of C-reactive protein, it's not known whether this happens at the level of biosynthesis or whether it results from decreases in interleukin-1. The significance of C-reactive protein also is at question. It may cause some destructive effects of rheumatic disease, or it may simply be a parallel but harmless artifact.

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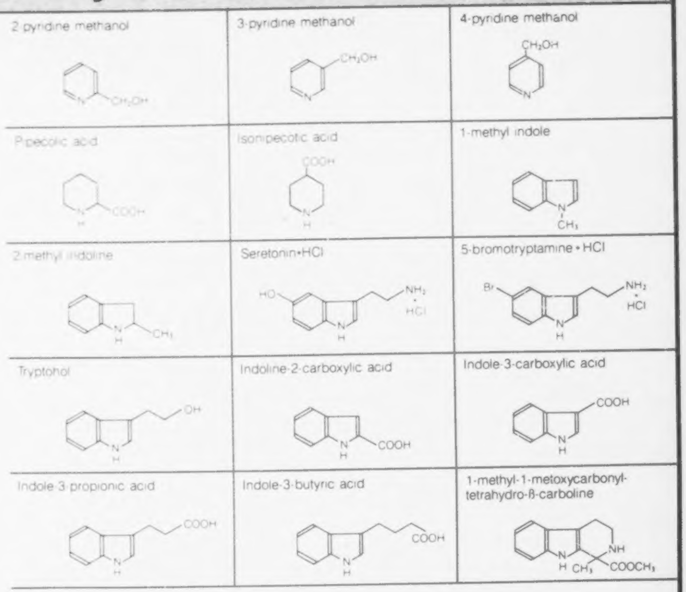

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2-Bromo Thiophene
4-Chlorobenzophenone
Cinnamyl Chloride
2, 6-Dimethoxybenzoic Acid
2, 6-Dimethoxybenzoyl Chloride
Dimethylcyanoiminodithio carbonate
Dimethylamine HCl
2-Furoic Acid
2-Furoyl Chloride
-(2-Furylacrolein)
1-methyl-6-aminouracil
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3-methylbenzophenone
4-methylbenzophenone
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2-Methoxy Napthelene
(+ derivatives)
0-Nitro Benzaldehyde
Potassium Acetate (Solution)
Phenoxy Acetyl Chloride
Phenyl Acetyl Chloride
Theobromine
Thienyl-2-acetyl Chloride
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Thiophene-2-carbonyl chloride
2-Thienyl acetic acid
2-Thienyl Glyoxylic (+ esters)

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CIRCLE 35 ON READER SERVICE CARD

Sales of many nonsteroidal anti-inflammatories will fall

Drug (source)	Sales, $ million 1989	 1993	Average annual change, %
Naproxen (Syntex)	$ 370	$ 520	6%
Diclofenac (Ciba-Geigy)	270	440	47
Piroxicam (Pfizer)	248	235	−3
Sulindac (Merck)	170	105	−11
Flurbiprofen (Upjohn)	78	220	30
Ketoprofen (Wyeth)	55	80	8
Ibuprofen (Upjohn)	50	20	−24
Tolmetin (McNeil)	48	63	3
Ibuprofen (generic)	47	52	4
Fenoprofen (Distra/Lilly)	29	12	−27
Indomethacin (Merck)	29	12	−21
Indomethacin SR (Merck)	23	14	−17
Meclofenamate (Parke-Davis)	19	10	−17
Auranofin (SmithKline Beecham)	17	29	17
Indomethacin (generic)	17	13	−6
Ibuprofen (Boots)	9	5	−19
Nabumetone (SmithKline Beecham)[a]	7	130	b
Etodolac (Ayerst)[a]	6	85	b
Sulindac (generic)	c	40	b
Pirazolac (Berlex)	c	5	b
Oxaprozin (Searle)	c	42	b
Carprofen (Roche)	c	20	b
Fenbufen (Lederle)	c	20	b
Tenoxicam (Marion)	c	5	b
Piroxicam (generic)	c	45	b
Others	49	72	14
TOTAL	**$1541**	**$2294**	**11%**

a Assumes U.S. approval in 1989. **b** Not meaningful. **c** Not now approved in U.S. **Source:** Sanford C. Bernstein & Co.

Perhaps the best-known rheumatoid disease that NSAIDs are designed to treat is rheumatoid arthritis. About 2.1 million Americans are afflicted, according to the Arthritis Foundation in Atlanta. Of these, about 1.5 million are women and 600,000 men.

The disease can be difficult to diagnose. Osteoarthritis, which is nonrheumatoid, is more common, affecting about 16 million Americans. And such infectious diseases as gonorrhea and Lyme disease (infection by the spirochete *Borrelia burgdorferi*, transmitted by tick bites) cause their own forms of arthritis.

The Arthritis Foundation has published a scorecard of 11 criteria to aid diagnosis, including patterns of pain and joints involved, x-ray signs, and tests of blood, synovial (interior joint) fluid, and joint tissues. Seven positive signs denote "classic" rheumatoid arthritis, whereas five mean "definite," three "probable," and two "possible."

One sign of the autoimmune nature of rheumatoid arthritis is so-called rheumatoid factor in blood. Rheumatoid factor is antibody, usually of the immunoglobulin M (IgM) type, that reacts with human IgG. About 75% of rheumatoid arthritis patients have rheumatoid factor, though 5 to 10% of persons over age 60 also have it.

Also, large numbers of rheumatoid arthritis patients have a human leukocyte antigen (HLA) called DR4. HLAs are proteins embedded in outer surfaces of almost every human cell. Their pattern of occurrence is individual to each person and guides the immune system in distinguishing between cells, particles, and proteins that are "self" and "nonself." HLAs are coded for by a set of genes on chromosome 6 called the major histocompatability locus.

During routine immune surveillance, blood cells called polymorphonuclear (PMN) leukocytes ingest various proteins, particles, or other cells they find, degrade these internally, and present the products on their own surfaces. The PMNs then secrete interleukin-1, which activates other blood cells called T-cells to interact with these new antigens and the HLAs normally present to test for self versus nonself.

If the result is nonself, the T-cell secretes interleukin-2, which stimulates growth of other T-cells sensitive to that antigen. The T-cell also presents the antigen to other blood cells called B-cells and secretes interleukin-4 and a substance called B-cell differentiation factor. Interleukin-4 stimulates growth of B-cells sensitive to the antigen. The differentiation factor induces B-cells to produce antibodies against it.

Interleukin-1 has other widespread influences that include release of prostaglandins and potently oxidizing superoxide ($O_2{}^{1-}$) ions as well as destruction of bone and cartilage. This underscores the importance of finding drugs that inhibit production of interleukin-1 during inappropriate immune reactions against the body's own tissue.

Joint destruction of rheumatoid arthritis occurs at different rates in different patients. Thus doctors can manage from 50 to 75% of such patients on NSAIDs as sole drug therapy.

Physical and occupational therapy help to keep joints mobile and strengthen associated muscles. Proper balance of muscle contracture avoids deformation of joints. Psychological counseling may also be needed, as well as complete bed rest during severe flares of disease.

For patients in which NSAIDs do not arrest joint destruction, doctors must add "slow acting" or "disease-modifying" drugs. These include

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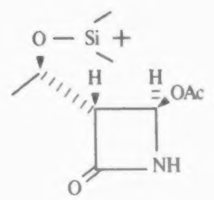
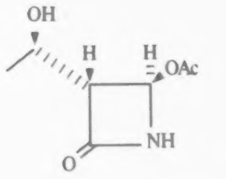
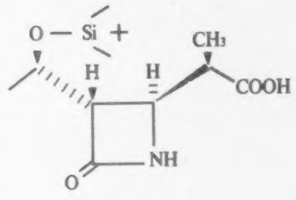


(3R, 4R)-4-Acetoxy-3-[(R)-(tert-butyldimethylsilyloxy) ethyl]-2-azetidinone (AZETIDON-KANEKA)



(3R, 4R)-4-Acetoxy-3-[(R)-hydroxyethyl]-2-azetidinone



(3S, 4S)-3-[(R)-(tert-Butyldimethylsilyloxy) ethyl]-4-[(R)-carboxyethyl]-2-azetidinone

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CIRCLE 79 ON READER SERVICE CARD

Pfizer photo

Researcher uses electron micrograph to study inflammatory cells produced in arthritic joint disease

gold salts, penicillamine, antimalarials, cytotoxic agents, and immunosuppressants. The way in which these drugs arrest the rheumatoid process is mostly unknown, and patients must take them for four to nine months to see if they can be tolerated or if they work at all. Analyst Habermas predicts that doctors will move more aggressively in the future to prescribe such drugs.

Gold salts include injectable gold sodium thiomalate and gold thioglucose. SmithKline Beecham has recently received FDA approval to market Ridaura brand of auranofin, an acetylated gold thioglucose, which has the advantage of being an oral drug with lower incidence of side effects, but which also may be less effective than the injectables.

If gold fails, doctors can turn to penicillamine or the antimalarials chloroquine or hydroxychloroquine. Also available are the cytotoxic drugs cyclophosphamide and methotrexate. Lederle Laboratories, Pearl River, N.Y., introduced Rheumatrex, an oral form of methotrexate for rheumatoid arthritis last January.

Patients take only 7.5 mg of Rheumatrex once weekly. This contrasts with the 20- to 12,000-mg daily doses given as cancer chemotherapy. Because of the unusual antiarthritic dosage of one 2.5-mg tablet three times in the 24-hours of one single day a week, Lederle has packaged the tablets in special blister packs of three. This packaging, together with the doctor's instructions, helps patients keep to this rigid pattern.

Medicinal chemists also have given attention to such immunosuppressant drugs as cyclosporin A and FK-506. Both compounds are macrocycles, but cyclosporin A is a polypeptide and FK-506 is a lactone-lactam. Though cyclosporin A is an established drug used thus far to suppress rejection of transplanted organs, there is even greater interest in FK-506, because it is 100 times more powerful. FK-506 was discovered at Fujisawa Pharmaceutical Co. in Japan, and its total synthesis has been achieved by chemists at Merck, Rahway, N.J. (C&EN, Feb. 6, page 29).

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Michael J. Schmidt of Merck notes that cyclosporin A dramatically shuts down production of interleukin-2 and has been effective in treating rheumatoid arthritis. The compound damages patients' kidneys in long-term therapy, however, and any agent for rheumatoid arthritis must be safe in chronic dosages.

FK-506 stops production of interleukin-2 and -4 as well as another immunologic substance called interferon-γ, apparently by preventing syntheses of messenger ribonucleic acids (mRNAs) for those proteins. But FK-506 is also toxic to kidneys.

Now that total synthesis of FK-506 is complete, however, Merck chemists can make analogs that may have the immunosuppressant effect but lack the toxicity. Success hinges on whether toxicity is mechanism-based or idiosyncratic, Schmidt says. If mechanism-based, then the whole class of drugs will be toxic by their very mode of action, and the outlook is dim. But if it is unique to one compound, there is hope of developing a successful agent.

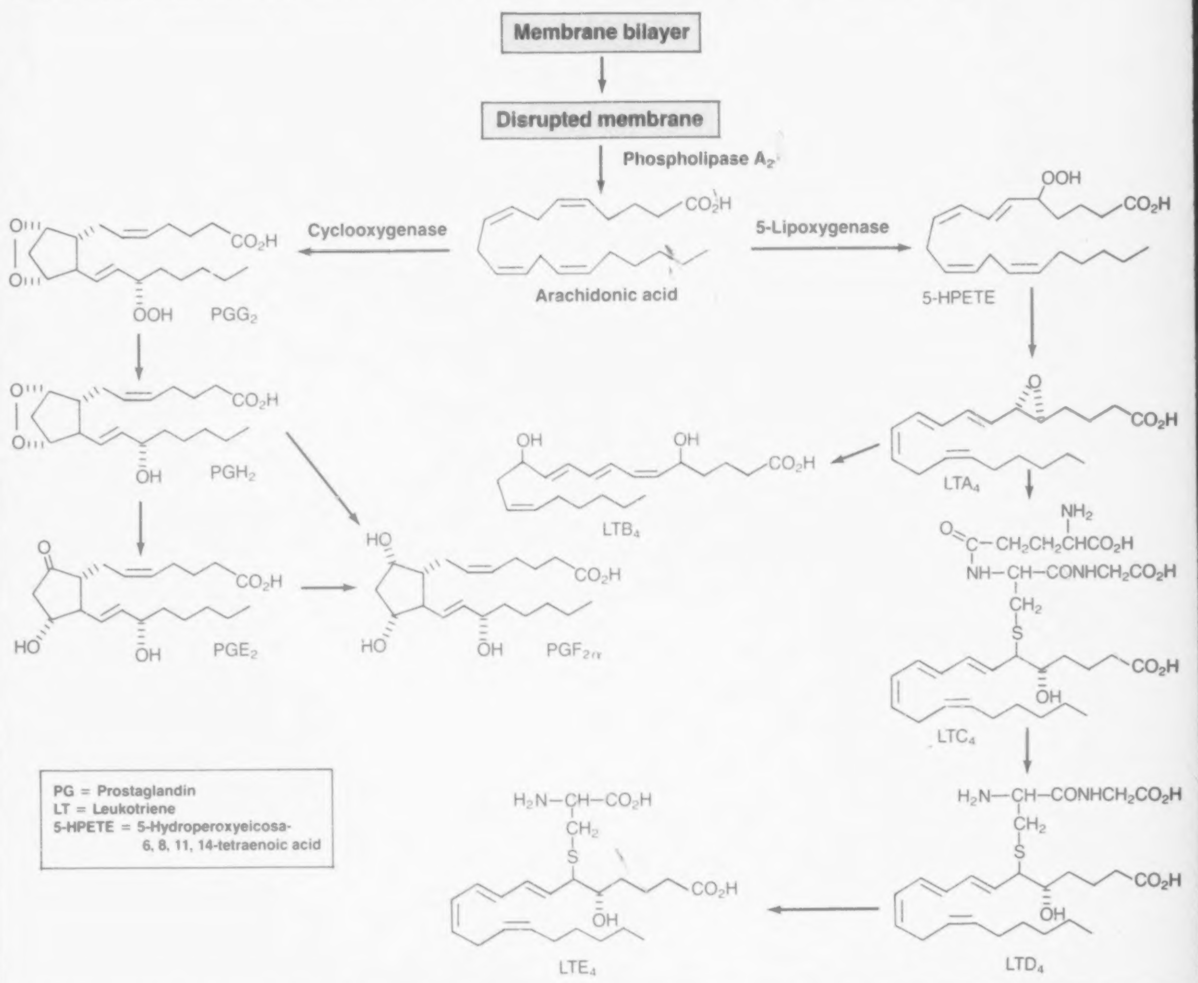
Two diseases related to rheumatoid arthritis are juvenile rheumatoid arthritis and ankylosing spondylitis (intervertebral inflammation that causes fusion of vertebrae).

Juvenile rheumatoid arthritis is actually three or more diseases, classified according to whether they affect few joints, many joints, or have systemic effects throughout the body. The Arthritis Foundation estimates that about 71,000 children under age 16 are afflicted, 61,000 of them girls.

Treatment is the same as for rheumatoid arthritis, relying on NSAIDs, physical therapy, and education, and going on to disease-modifying drugs if necessary. There is special concern to avoid joint deformity and ensure normal growth, because patients are growing children. For this reason, oral steroids are not given long-term, though steroid injections directly into joints may help severe disease. Doctors are divided on whether gold salts are truly effective in the juvenile diseases.

Many juvenile arthritis patients and 90% of those with ankylosing spondylitis have HLA B27. But 5 to 10% of normal persons also have this antigen, which points up the

Cascade of reactions of arachidonic acid produces mediators of inflammation



PG = Prostaglandin
LT = Leukotriene
5-HPETE = 5-Hydroperoxyeicosa-6, 8, 11, 14-tetraenoic acid

lack of fundamental understanding of rheumatoid disease.

In spite of its name, ankylosing spondylitis can also affect large joints and cause anterior uveitis, which is an inflammation of the iris of the eye. The Arthritis Foundation estimates that 318,000 Americans have ankylosing spondylitis, of whom 229,000 are men. Treatment includes NSAIDs, but the slow acting, disease-modifying drugs seem ineffective.

Though not a rheumatoid disease, osteoarthritis, also called degenerative joint disease, is a widespread, devastating condition that is treated similarly. The Arthritis Foundation estimates that 15.8 million Americans suffer from osteoarthritis, of whom 11.7 million are women.

Osteoarthritis involves destruction of cartilage and excess bone growth at joints, apparently from processes intended to repair normal wear and tear. Slight signs of it can appear between ages 10 and 30, and almost all persons have such joint changes by age 70. Occurrence of osteoarthritis as a disease depends on how fast the process works in individuals and whether pain and joint stiffening appear. The much greater incidence in women than in men leads many doctors to think that steroid hormones may be involved.

Cartilage consists of a matrix of glycoprotein fibers containing cells called chondrocytes. Chondrocytes multiply and synthesize matrix proteins and sugars in response to minute injuries or repetitive impact.

Because cartilage lacks blood vessels, it depends on nutrients from synovial (interior joint) fluid on one side and bone on the other. Compression of the joint squeezes fluid containing metabolic wastes out of cartilage, which is 70% water, into synovial fluid. Release of compression allows reabsorption of nutrient-containing fluid.

The aging process, whatever that may be, causes cartilage to lose this resilience. Minute injuries can result in release of prostaglandins and interleukin-1 into the joint. Among

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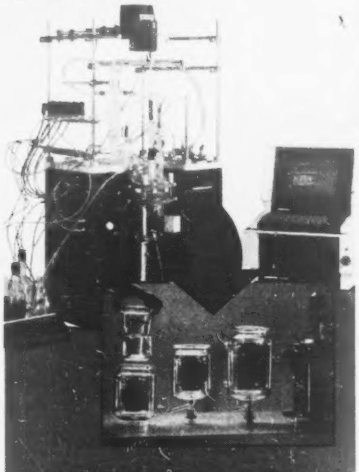

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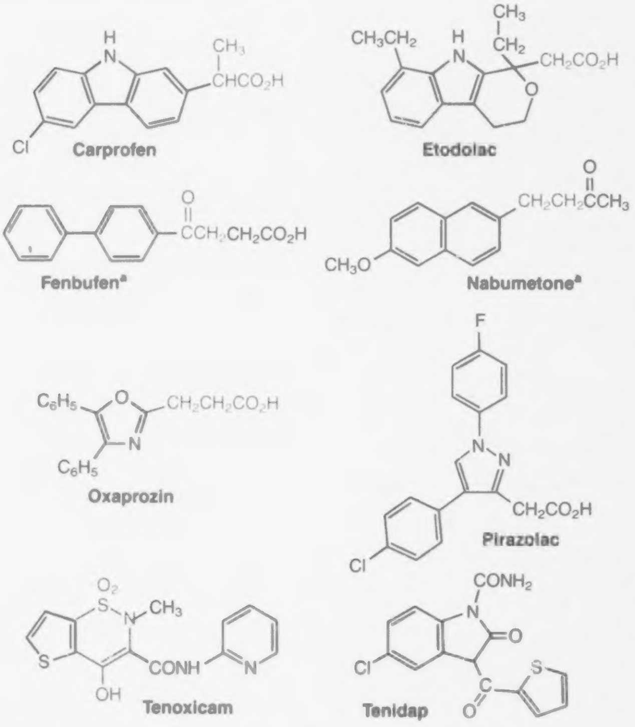
CIRCLE 9 ON READER SERVICE CARD

New anti-inflammatory drugs await U.S. approval



Note: Groups of atoms in color are those that make each compound a member of its class.
a Active metabolite is RCH_2CO_2H.

other things, interleukin-1 can stimulate production of cartilage-destroying enzymes.

As cartilage degrades, bone tissue grows in a density greater than normal at the bone ends. Some new bone growth occurs as sharp spurs. The denser, stiffer, new bone is susceptible to microfractures with constant use of the joint. These microfractures can stimulate more bone growth and cartilage destruction.

In x-rays, doctors can see dense new bone, appearance of spurs and microfractures, and a narrowing of the space between bone ends. Treatment includes the same physical therapy and NSAIDs as for rheumatoid arthritis. In addition, such muscle relaxants as high-dose diazepam may be needed to ease pain of muscles that lock in a stiffened state in response to joint damage.

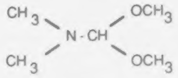
A rheumatoid disease that can affect any or all tissues of the body is systemic lupus erythematosus (SLE, "red wolf disease"). This disease takes its name from a red rash that sometimes forms on patients' cheeks and that, in some, gives the face a wolflike appearance. Though most SLE patients develop rashes of some sort and have abnormally photosensitive skin, the classic "butterfly" rash appears in fewer than half.

Based on findings of some epidemiologists, the Arthritis Foundation has estimated that there are 131,000 SLE patients in the U.S., 117,000 of them women. But spokesmen for the American Lupus Society in Torrance, Calif., say that a more likely number is 200,000. There is agreement that about 90% of SLE patients are women, and that greater numbers of black women are afflicted than white.

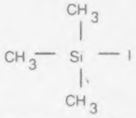
Symptoms vary widely, and SLE can mimic many other diseases. Some symptoms seem nonspecific,

DAVOS

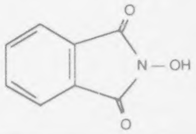
N,N-Dimethylformamide Dimethyl Acetal



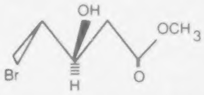
Trimethyl Silyl Iodide



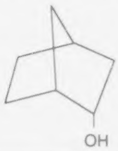
N-Hydroxy Phthalimide



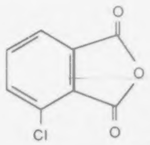
Methyl-(S)-(-)-4-Bromo-3-Hydroxybutanoate



(1S, 2R, 4R)-endo-Norborneol



3-Chloro Phthalic Anhydride



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Product Report

such as chronic fatigue, fever that comes and goes, joint pain, swollen glands and/or spleen, and a general feeling of being unwell. The disease flares and goes into remission. Patients often recognize onset of chronic fatigue as a warning sign of a new flare.

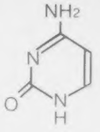
Other symptoms can be more dramatic but no less baffling, such as psychotic episodes and seizures resembling grand mal epilepsy. And the kidney is very susceptible to attack. Though early diagnosis and improved treatment have raised 10-year survival rates to about 90%, half of all deaths of SLE patients are from kidney disease.

With SLE as in rheumatoid arthritis, doctors usually depend on a scorecard of 11 criteria developed by physician Eng M. Tan at Scripps Clinic & Research Foundation, La Jolla, Calif. These are the butterfly rash, discoid (plaquelike) rash on other parts of the body, rash from overexposure to sunlight, ulcers in the mouth, arthritis in two or more joints, inflammation of tissue sacs around the heart (pericarditis) or lungs (pleuritis), protein or blood cell debris in urine, seizures or psychosis, low counts of certain blood cell types, antibodies to human cell nuclei, and any of certain other immunologic abnormalities. Doctors can diagnose SLE if any four of these symptoms are present.

Treatment is similar to that of rheumatoid arthritis, but tailored to individual cases. NSAIDs are effective against fever, joint pain, pericarditis, and pleuritis. Mouth ulcers and the various types of rashes may respond to chloroquine or hydroxychloroquine. Acute attacks of kidney disease, anemias involving various blood cell types, or psychiatric symptoms require high doses of oral or injected steroids like prednisone or methylprednisolone. These acute symptoms have also been treated with azathioprine, cyclophosphamide, and methotrexate, with and without steroids.

Pregnancy is a difficult problem for many female SLE patients. Miscarriages occur in about 25% of attempts, perhaps owing to blood clots in the placenta. And hormonal changes may cause severe flares in weeks following delivery. □

INTERMEDIATES FOR PHARMACEUTICALS



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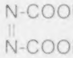
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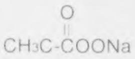
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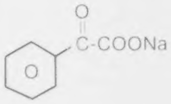

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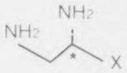

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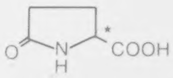

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OCTOBER 2[illegible]
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NEWS

1990 Employment Outlook

Companies strive to increase number of science graduates
Page 22

CHEMICAL & ENGINEERING NEWS

Volume 67, Number 43
CENEAR 67 (43) 1–72
ISSN 0009-2347

OCTOBER 23, 1989

News of the Week

- **San Francisco area earthquake left laboratories, plants shaken but in relatively good shape.** Page 4
- **Deficit-demanded budget cuts probably will leave science relatively unhurt.** Page 5
- **Aristech Chemical receives $25-per-share purchase offer from investment group headed by Jon M. Huntsman, chairman of Huntsman Chemical.** Page 5
- **President Bush's decision to continue making chemical weapons despite planned global disarmament treaty draws fire.** Page 5
- **National Medals of Science and Technology presented last week to 27 individuals during ceremonies in Washington, D.C.** Page 6

Cover: High school students tour Monsanto chemical plant in St. Louis

Letters 2

Concentrates

Business 7
Government 12
Science/Technology 17

The Departments

ACS News 41
Meetings 48
Newscripts 72

Business

Employment and salaries in chemical industry continue to increase, pushing up total industry compensation. Page 10

Degradable plastics may have significantly less impact on packaging market than was once thought. Page 11

Government

Environmental Protection Agency plans review of health and environmental safety effects of chlorofluorocarbon substitutes in effort to plan for safe, nontoxic alternatives. Page 14

Impact of leveraged buyouts as well as high costs of capital for research projects on the vitality of corporate R&D debated at recent conference. Page 16

Science/Technology

Complex Carbohydrate Structure Database developed at University of Georgia promises easier, more efficient searching for structures, information. Page 18

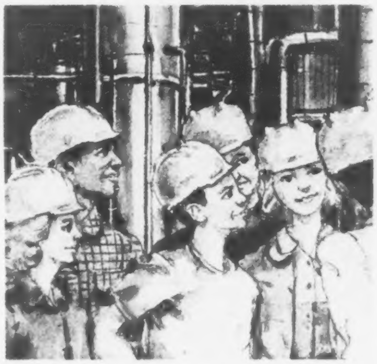
Center for Photoinduced Charge Transfer, one of 11 science and technology centers nationwide, opens at University of Rochester. Page 19

Books

"Pollution and the Struggle for the World Product" by H. Jeffrey Leonard leaves questions about potential links between environmental regulation and international economic competitiveness. Page 39

Awards

ACS winners: Nakanishi, Arnett, Bartlett, Grieco, Grubbs, Heathcock, Jorgensen, Schultz, Stille, Wasserman, and Wender. Page 42



Employment Outlook

C&EN's annual look at the job market focuses on efforts by industry to increase the number of science graduates and to improve precollege education. Page 22

Chemical & Engineering News
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LETTERS

Hands-on chemistry exhibits

SIR: The article on precollege science and math education by Ward Worthy (C&EN, Sept. 11, page 7) provided a welcome status report. I would like to add a note to what was written about science museums and chemistry exhibits as a vehicle for science education. Science museums play a significant educational role in both formal and informal ways. But chemistry is difficult to do in the form of interactive exhibits. That is largely why chemistry has been sparsely represented in science museums.

The National Science Foundation has funded a collaboration between the New Curiosity Shop (NCS) and the California Museum of Science and Industry (CMSI) for development of hands-on chemistry exhibits. NCS has designed and developed 15 prototype hands-on chemistry exhibits that will form the interactive core of the "Molecules in Motion" exhibit mentioned in the article. The prototypes will be tested in the museum environment with several hundred visitors during October. CMSI will then incorporate the exhibit ideas into the designs for its chemistry gallery.

In addition, NCS will further refine some of these and other of its chemistry exhibits and produce copies for sale to science museums. These exhibits will provide the public of all ages with inviting, fun, understandable, concrete experiences with real chemical phenomena. The goal is to provide an avenue for reaching many people with the message that chemistry is intriguing, ubiquitous, important, and comprehensible at many levels.

Dan Chabay
President, New Curiosity Shop
Mountain View, Calif.

Auto emission control

SIR: In a letter to the editor (C&EN, Aug. 21, page 4), Rubin Weiner states that "bigger engines gulp more gas . . . and spew out more emissions." This is true for carbon dioxide to the extent that bigger engines use more fuel, but it is not true of the tailpipe emissions that are contributing to our current urban ozone and carbon monoxide nonattainment problems. Those emissions are controlled on a grams-per-mile basis, not on a grams-per-gallon basis. This is a common misunderstanding, because it seems so normal to believe that more gasoline going into the engine means more pollutants coming out.

In fact, a case can be made that more efficient cars worsen urban air pollution. Greater efficiency reduces the cost of driving, which, according to economists, increases the amount of driving done. Emissions increase as mileage driven increases even when gasoline consumption goes down, as it has done for most of the past decade.

Correcting this little misunderstanding will undoubtedly not change Weiner's views of the auto industry, but perhaps it will help clarify the relationship between fuel economy and tailpipe emissions.

There have been occasional calls for emission standards based on grams per gallon, so that reductions in gasoline consumption would be reflected in reductions in emissions. Neither the Environmental Protection Agency nor Congress has been very interested in changing the regulatory system, which is complicated and is working. The proposal for emissions averaging in the Administration's proposed Clean Air Act amendments would be a move in the direction of a surrogate grams-per-gallon standard, if one assumes that the more energy-efficient cars would be the ones with the lower-than-average emission levels and the less energy-efficient cars would be the ones with the higher-than-average emission levels.

David E. Gushee
Senior Specialist in
Environmental Policy
Washington, D.C.

Nuclear waste disposal

SIR: Edward J. Fritz has again assured us (C&EN, June 5, page 33) that high-level nuclear waste gives off too much heat to be buried. Why? Does waste spacing matter? Or rock type? Stress or lack thereof? Water content? Cooling time before burial? Simply saying there is "too much heat" is a very superficial judgment. Or is nuclear heat too much in any amount?

At the proposed Yucca Mountain repository, most of the waste canisters would be sized so as not to exceed a centerline temperature of 300 °C when the repository reaches its maximum temperature. The lower temperature in the surrounding welded volcanic tuff can be easily tolerated. Even at higher temperatures, the possibility of stress-induced fissures would be of little concern because of the waste depth and the dry climate.

Sweden is pursuing disposal in granite, with studies of migration of ele-

Growing Employment, Salaries Push Up Chemical Industry Compensation

Growing employment and increasing wages in the chemical industry continue to push up total personal earnings.

According to a Department of Commerce study, personal earnings for employees in the chemicals and allied products industry in the 50 states plus the District of Columbia rose last year to $44.34 billion, an increase of 9.5% from the year before. Personal earnings are total compensation, excluding fringe benefits, paid to employees.

The 9.5% increase for chemicals and allied products is well ahead of that for personal earnings for the U.S. as a whole—including all manufacturing and service industries—which rose 7.7% to $2.97 trillion. It also ranks ahead of the increase for total personal income, which rose 7.6% to $4.05 trillion. Personal income is earnings less payments for social security, medicare, and other social insurance programs, plus dividends, interest rent, and transfer payments. In 1987, chemical personal earnings rose 4.2%, compared with 7.0% for all personal income.

Of all U.S. industries, chemicals contributed about 1.5% of total earnings and about 1.1% of total personal income last year. This is about the historical norm for the industry.

Combining the Commerce Department figures with Labor Department data relating to total average annual employment shows that earnings per chemical employee nationwide last year totaled about $41,653, up 5.5% from the year before. In 1987, earnings per chemical employee increased only 3.7% from 1986; however, this figure has increased at an

New Jersey ranks first in personal income derived from chemical industry

Rank 1988	State	$ Millions	% change from 1987	% of total state personal income	% of total U.S. chemical income
	NEW ENGLAND	$ 1,978	7.1%	0.8%	4.5%
18	**Connecticut**	1,048	2.5	1.4	2.4
43	**Maine**	26	4.0	0.1	0.1
23	**Massachusetts**	741	14.0	0.6	1.7
40	**New Hampshire**	44	15.8	0.2	0.1
38	**Rhode Island**	100	5.3	0.6	0.2
46	**Vermont**	19	5.6	0.2	nm
	MID-ATLANTIC	12,903	11.0	1.6	29.1
9	**Delaware**	1,679	6.5	14.4	3.8
49	**District of Columbia**	17	6.3	0.1	nm
25	**Maryland**	480	8.6	0.5	1.1
1	**New Jersey**	5,411	11.5	3.2	12.2
5	**New York**	2,658	10.9	0.8	6.0
4	**Pennsylvania**	2,659	13.6	1.4	6.0
	GREAT LAKES	8,751	8.1	1.3	19.7
7	**Illinois**	2,474	8.3	1.2	5.6
12	**Indiana**	1,348	4.3	1.6	3.0
8	**Michigan**	1,897	10.5	1.2	4.3
6	**Ohio**	2,626	8.2	1.6	5.9
17	**Wisconsin**	406	8.3	0.5	0.9
	PLAINS	2,150	7.6	0.8	4.8
31	**Iowa**	206	6.7	0.5	0.5
29	**Kansas**	281	6.0	0.7	0.6
15	**Minnesota**	1,219	8.8	1.7	2.7
17	**Missouri**	1,119	8.3	1.4	2.5
32	**Nebraska**	205	8.5	0.9	0.5
42	**North Dakota**	41	2.5	0.5	0.1
40	**South Dakota**	44	4.8	0.5	0.1
	SOUTHEAST	10,275	6.7	1.2	23.2
26	**Alabama**	438	6.8	0.8	1.0
33	**Arkansas**	177	4.7	0.6	0.4
20	**Florida**	811	6.4	0.4	1.8
22	**Georgia**	643	6.5	0.7	1.5
24	**Kentucky**	518	7.2	1.1	1.2
14	**Louisiana**	1,284	8.7	2.4	2.9
30	**Mississippi**	216	3.8	0.7	0.5
10	**North Carolina**	1,505	7.1	1.6	3.4
13	**South Carolina**	1,307	13.7	2.9	2.9
11	**Tennessee**	1,395	3.0	2.1	3.1
16	**Virginia**	1,161	2.0	1.1	2.6
19	**West Virginia**	821	6.9	3.7	1.9
	SOUTHWEST	4,199	11.6	1.2	9.5
35	**Arizona**	134	24.1	0.3	0.3
49	**New Mexico**	17	0.0	0.1	nm
36	**Oklahoma**	109	7.9	0.3	0.2
2	**Texas**	3,939	11.4	1.6	8.9
	ROCKY MOUNTAIN	599	9.5	0.6	1.4
28	**Colorado**	317	3.3	0.6	0.7
34	**Idaho**	137	10.5	1.1	0.3
46	**Montana**	19	5.6	0.2	nm
37	**Utah**	106	27.7	0.5	0.2
45	**Wyoming**	20	25.0	0.3	nm
	FAR WEST	3,485	17.0	0.5	7.9
3	**California**	2,832	17.7	0.5	6.4
44	**Nevada**	25	0.0	0.1	0.1
39	**Oregon**	71	6.0	0.2	0.2
23	**Washington**	524	16.4	0.7	1.2
46	**Alaska**	19	0.0	0.2	nm
51	**Hawaii**	13	8.3	0.1	nm
	TOTAL	$44,340	9.5%	1.1%	100.0%

Note: Totals may not add due to rounding. nm = not meaningful.
Source: Department of Commerce

average annual rate of 5.6% since 1984.

Regionally, personal earnings totals from the chemical industry are highest in the Middle Atlantic states, according to the Commerce study, with total personal earnings of $12.9 billion in 1988, up 11% from the previous year. This is about 1.6% of total regional personal income and about 29% of total U.S. earnings from chemicals.

The Middle Atlantic region is followed by the Southeast, with a total of almost $10.3 billion in earnings derived from the chemical industry. This shows a year-to-year growth of about 6.7%. Earnings from chemicals in this region make up about 1.2% of total regional personal income and about 23% of U.S. chemical earnings.

From here earnings fall off rapidly by region. In the Great Lakes states, earnings in 1988 totaled $8.75 billion, up 8.1% from the year before and contributing about 1.3% of regional personal income and about 20% of total U.S. chemical earnings. Earnings in the Southwest totaled almost $4.20 billion, up 12%. This was 1.2% of state income and 9.5% of U.S. chemical earnings. These were followed by the Far West at $3.49 billion, up 17%; the Plains states at $2.15 billion, up 7.6%; and New England, $1.98 billion, up 7.1%.

The poorest region by far for chemical earnings comprised the five Rocky Mountain states, where those earnings were only $599 million. Although this was an increase of 9.5% over the previous year, it was just 0.6% of regional personal income and a scant 1.4% of total U.S. chemical earnings.

To find the number one state in total chemical earnings, don't look at Texas, with its great number of chemical plants centered around Houston. Texas is a distant second at $3.94 billion. The number one state is New Jersey with its concentration of drug industries and chemical headquarters and production. New Jersey's personal earnings from chemicals totaled $5.41 billion.

To fill out the Top 10, California is third at $2.83 billion, followed by Pennsylvania and New York in a tie at $2.66 billion, Ohio at $2.62 billion, Illinois $2.47 billion, Michigan $1.90 billion, and North Carolina $1.51 billion.

At the bottom of the list is Hawaii, whose $13 million was beat out not only by New Mexico at $17 million, but also by the District of Columbia (also at $17 million) with its public relations officers and others paid by the chemical industry.

It is in terms of year-to-year growth that some of the smaller states come into their own. The largest growth for the year was seen in Utah, where Huntsman Chemical has made its headquarters, at 28%. This is followed by Wyoming at 25%, perhaps heralding a healthy soda ash industry.

Following these are Arizona with a 24% rise, California 18%, Washington 16%, New Hampshire a little less than 16%, Massachusetts 14%, South Carolina and Pennsylvania, each a little less than 14%, and New Jersey almost 12%.

Not surprisingly, Delaware, with its small size and large concentration of chemical companies, leads in the chemical earnings as a percentage of total state personal income, at 14%. Interestingly, the second largest contributor to personal income there is state and local government, at $920 million, or 7.9%.

Delaware is followed at a far distant second by West Virginia at 3.7%, then New Jersey 3.2%, South Carolina 2.9%, Louisiana 2.4%, and Tennessee 2.1%. From there the percentages all cluster between as little as 0.1% and 1.7%.

This year, earnings of those employed in the chemical industry undoubtedly will rise again. However, the growth probably will not match the 9.5% yearly increase of 1988. Employment in the industry, although still increasing, is not moving forward as fast as it did last year. And wage increases are still holding at moderate levels.

William Storck

Limited impact seen for degradable packaging

The impact of degradable plastic films on certain packaging end-use markets may be significantly less than once thought. According to a recent study by Kline & Co., a New Jersey-based consulting firm, degradable films will account for only 11% of their 2.8 billion lb market potential by 1994. At current levels, this means that degradable films would make up about 5% of the total packaging film market.

To reduce solid waste and litter, degradable plastic films are expected to be targeted by consumers and legislators for six end-use areas: compost bags, grocery sacks, merchandise bags, trash bags, garbage bags, and diaper backing. However, the study reports, only compost bags, with 54% in degradable films, will account for a significant portion of the films' market potential. Figures for the remaining five markets show degradable films at levels of 17% in merchandise bags, and 11% or much less in the other areas.

Because of increased consumer interest, firms such as Mobil have started producing degradable plastic bags made from polyethylene. Degradable plastics, especially those that are biodegradable, can cost significantly more to produce, says Mobil. Biodegradable plastics based on cornstarch are being manufactured by companies such as Archer Daniels Midland and St. Lawrence Starch. Ampacet, among others, is using additives to promote photodegradability in plastic films.

However, there are problems associated with the degradable materials. Often, they will only degrade with relatively long exposure to the environment. Research at the University of Arizona has shown that burying most degradable substances in landfills will inhibit their breakdown for decades.

The Kline & Co. report suggests that the waning support of decisionmakers will influence the decreased impact of degradable plastics in packaging film markets. The Environmental Protection Agency, in a 1988 report on solid waste, along with plastics industry trade associations and certain environmental groups, shows more support for managing solid waste through a four-step process involving reduced use, recycling, incineration, and landfilling.

Ann Thayer

1990 Employment Outlook

Bette Hileman, C&EN Washington

◆ Career Opportunities for Chemical Professionals

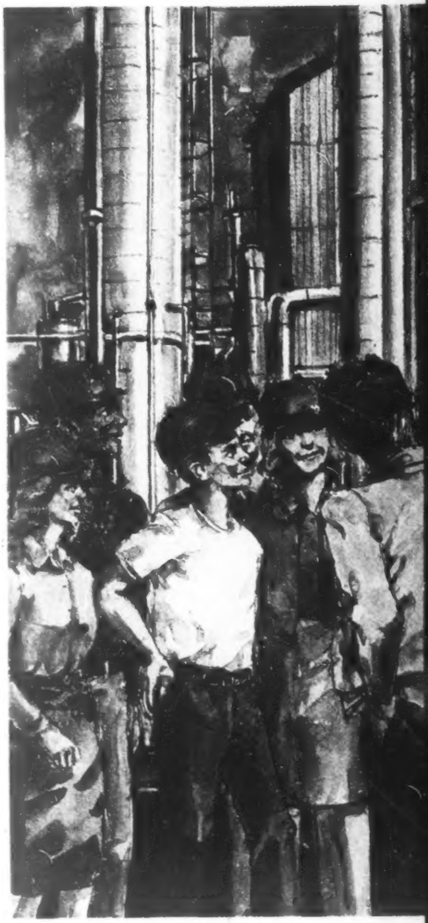
The employment market for chemical professionals was more robust this year than at any time in the recent past. Recruiters report that there seemed to be more jobs, particularly for B.S. and M.S. chemical engineers and Ph.D. chemists, than there are candidates to fill them. As a result, both chemists and chemical engineers are getting higher salaries. Furthermore, some companies even began to offer bonuses to new graduates who accept job offers. Also, companies believe they may need to hire more foreign graduates who do not have permanent residency status in the U.S. And more job candidates this year have been bidding one firm against another for salaries.

◆ Industry Strives To Increase Science Graduates

In response to an impending shortage of scientists and engineers, industry is using a variety of techniques to increase the supply of graduates and to improve precollege education so students will be prepared and motivated to enter these fields. Page 23

◆ Demand

Demand for chemical professionals, strong in 1988, is even stronger this year. For B.S. and M.S. chemical engineers, especially, there appears to be a tightening supply-demand crunch. According to the College Placement Council's survey, the number of offers for chemical professionals rose markedly. And the latest ACS employment clearinghouse had more jobs listed than candidates seeking positions. Page 29



◆ Salaries

Starting salaries for newly graduated chemical professionals are up at all degree levels this year. For chemical engineers, they rose 6% at the B.S. and Ph.D. levels and 9% at the M.S. level. Salaries of experienced chemists rose just enough to keep up with inflation. Page 33

◆ Career Planning

The American Chemical Society and other organizations can provide a variety of useful information to people seeking advice about careers in chemistry and chemical engineering. This section lists services, sources of information, and organizations that can supply guidance about careers. Page 35

Industry Strives To Increase Science Graduates

Industry is using an array of techniques to encourage more students to major in science and engineering

A crisis is developing in the supply of scientists and engineers entering the work force. That is the consensus of the National Science Foundation, some academic personnel, and many leaders in the chemicals and allied products industry.

NSF predicts that by the year 2006 the U.S. will have a cumulative shortfall of 675,000 people with bachelor's degrees in natural science and engineering. Similarly, NSF projects that by 2006, 24,000 new jobs in these fields requiring Ph.D.s will be created annually, but only 10,000 Ph.D.s will be granted. Even if salaries respond enough to increased demand to attract more Ph.D. candidates, there likely will be an annual shortfall of 7800 Ph.D.s. Already, the shortage is becoming evident. This year for the first time since the late 1970s, recruiters report that there seem to be more jobs for new B.S. chemical engineers and Ph.D. chemists than there are qualified candidates to fill them.

In response to this impending crisis, the chemical industry and others have taken a number of steps to attract more students into science and engineering and to improve precollege science and math education so students will be prepared and motivated to enter these fields. Efforts are being made at nearly all educational levels—precollege, undergraduate, and graduate but the major focus of industry's efforts has been directed at high schools and middle schools.

At the annual meeting of the Council for Chemical Research early this month in Parsippany, N.J., Mary L. Good, senior vice president for technology at Allied-Signal, said, "About the year 2000, the shortage of Ph.D.s [in science and engineering] will become critical. If we expect to have the human resources we need to sustain our research endeavor, we are going to have to find better ways to interest more of our people in math and science."

Why is a large shortfall in scientists and engineers predicted for the near future? Only a few years ago, there was such an excess of chemical engineering graduates that many couldn't find work and large numbers of chemists were being laid off in early-retirement programs.

Several factors will probably contribute to the shortage. First, industry, academia, and government are expected to employ a steadily increasing number of scientists and engineers over the next 20 years. The chemical industry, as well as much of the rest of the economy, is increasingly dependent on highly trained scientists and engineers to maintain profitability and develop new products. "The high-technology economy requires an extraordinary investment in basic scientific research. It is knowledge- rather than energy-, resource-, or personpower-intensive," says Edward J. Bloustein, president of Rutgers University.

At the same time that the number of job openings is expected to rise, the college-age population in the U.S., which has been declining since 1980, will continue to decrease through 1996. Census Bureau figures indicate the population of 18- to 24-year-olds will reach a low of 24 million in the mid-1990s, compared with 30 million in 1980. In addition, a smaller and smaller part of this diminishing number of students is choosing to pursue science majors. In 1973, 11% of college freshmen intended to major in biological or physical sciences or mathematics. By 1988, that percentage had dropped to 6%. The number of bachelor's degrees in chemistry awarded last year was the lowest in two decades.

Another factor that is expected to contribute to a decreasing pool of scientists is that by the end of the century, only 15% of net new entrants to the labor force will be white males. Currently, the vast majority of scientists and engineers are white males.

Unless the proportion of white men that major in science or engineering rises dramatically, women, blacks, Hispanics, and new immigrants will have to make up the shortfall. Yet most members of these groups have traditionally shunned science and engineering careers. For example, in 1987 blacks earned a total of 12 of the 3716 engineering doctorates awarded and only 16 of the 3210 Ph.D.s in physical sciences. The number of B.S. degrees in science and engineering granted to blacks and Hispanics was actually lower in 1985 than in 1979. Moreover, women, though their share now is greater than in the past, were awarded last year only 16% of the doctorates in physical sciences and 7% in engineering.

Already now for more than a decade, chemistry and chemical engineering departments in colleges and universities have not been able to recruit enough U.S. citizens as graduate students. They have filled their excess openings with foreign students. In 1987, for example, foreign students earned 40% of the Ph.D.s in chemical engineering.

A final contributing factor that dims the prospects for recruiting enough students into science and engineering is that the achievement of U.S. elementary and high school students in science is very low when compared with that of other developed countries.

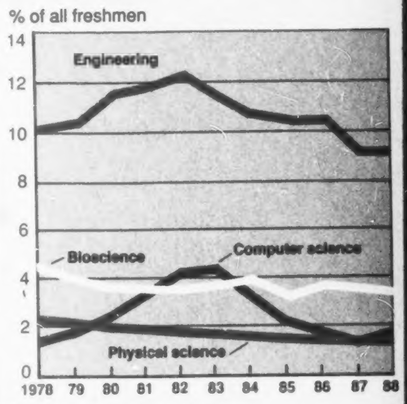
In 1988, the International Association for the Evaluation of Educational Achievement compared the science achievement of students in 15 developed countries. It found that at the fifth-grade level, U.S. students stood about in the middle, similar to students in Italy and Australia, while Japan and Korea led. But by the ninth grade, American students ranked next to the last; only Hong Kong was lower on the scale. Ninth graders in Hungary headed the list, followed by Japan and the Netherlands.

Even when only those students taking advanced high school courses in science were compared, U.S. students ranked in the middle in physics, third from the last in chemistry, and at the bottom in biology. Apparently, something happens to turn off the U.S. students to science between the fifth and ninth grades, and to dampen the achievement of even the best students in high school.

To better prepare students so they have the background and motivation to study science and engineering, and to encourage able college-age students to major in these fields, industry, either independently or in partnership with government or academia, has initiated or joined a great many programs to improve college and precollege education.

Good: shortage will be critical

Fewer freshmen have planned sciences or engineering major



Source: American Council on Education

Some of the programs are aimed directly at increasing the supply of scientists and engineers. Others, such as research grants, have multiple purposes, only one of which may concern supply or educational quality.

Industry provides a great deal of financial aid to undergraduate and graduate education. Nearly 90% of these funds supports specific research projects or specific research areas in which the company has an interest. The aid that industry gives for such research has a direct effect on the supply of graduate students because much of it is used for fellowships, thus creating new openings for graduate students. The amount of corporate support for chemistry and chemical engineering departments has increased markedly since 1981. For example, surveys carried out by the Council for Chemical Research show that industrial support per faculty member in the chemical engineering departments responding to the survey increased from $10,540 in 1981 to $33,860 in 1987. For chemistry department respondents, the percentage increase was even greater: The support grew from $3300 per faculty member in 1981 to $13,340 in 1987.

The approximately 12% of corporate funds that are uncommitted also may serve to increase the number of graduate students. Some of these funds are used by department heads to identify promising undergraduates and pay for their visits to graduate schools, where they are informed about the programs, for example.

Corporate aid to chemistry and chemical engineering departments also serves to attract more graduate students by improving the general quality and prestige of these departments. It makes it possible for them to do some kinds of important research that would otherwise be too expensive.

The effect of industry's support on undergraduate education is less clear. Some of the discretionary funds that companies provide are used to recruit undergraduates and thus help increase the number of science and engineering majors. According to John T. Lund, executive director of the committee on educational aid at Du Pont, department heads often use part of these discretionary funds to send representatives to high schools to try to explain the value of chemistry and chemical engineering.

But the research money industry provides chemistry and chemical engineering departments has both a positive and negative effect on undergraduate recruiting and retention. At the same time that it increases the prestige of the department and thereby attracts more undergraduates by providing stimulating, and sometimes personally lucrative, research opportunities for faculty members, it may divert them away from another important function—providing high-quality teaching for undergraduates. Most observers recognize that research is an important component of higher education. Some believe, however, that the increased focus on research has caused faculty members to lose contact with undergraduates.

Many in academia are concerned that undergraduate chemistry classes are taught too often by the least qualified instructors in large classes and uninspiring labs. Consequently, large numbers of students who might otherwise be interested in chemistry are turned off, they say. These critics claim that some chemistry faculty members concentrate too much on research.

Porter: academic Ph.D. recruitment

"Faculty members are urged to become entrepreneurs, to start companies, to obtain patents, to acquire venture capital, and to establish international reputations," says Glenn A. Crosby, professor of chemistry and chemical physics at Washington State University. "The system is badly out of balance," he adds. "Teaching is often left to those who can't make it in research."

The Council for Chemical Research has established a committee that solicits unrestricted funds from member industries and gives these funds to chemistry and chemical engineering departments to use in any way they see fit. Recipients consider these funds very useful because they are untargeted and can be used in critical areas for maximum impact. By strengthening the departments or being used for recruiting, this money may help attract more students into chemistry and chemical engineering. However, the unrestricted funds collected by the Council for Chemical Research have declined from a high of $675,000 in 1985 to about $450,000 in 1989, when they were just slightly higher than in 1988.

Some companies that hire chemical professionals also support cooperative students. These students work full-time at a particular company for two or three semesters during the regular four undergraduate years and take courses during the summer to make up the material they missed during the nine-month school year. Cooperative programs expose students to the practical applications of their courses in industry and thereby may help motivate some who would otherwise change their majors from science or engineering into some other field. In 1988, Congress' Office of Technology Assessment recommended cooperative programs as one way to motivate students and keep them from dropping out of science and engineering majors.

These programs have been going on for decades. However, a number of companies that never before had such programs are now starting them, says Daniel T. Hanson, job coordinator for the chemical engineering department at Texas A&M University.

In addition, in the past few years, some firms that hire chemical professionals have increased the number of scholarships and fellowships they provide. For example, Phillips Petroleum has raised its undergraduate scholarship support at least 30% in the disciplines that are in short supply for the company, says William K. Dausses, director of employment and placement. Phillips also

Roger Timmer (left), an employee of Lacks Industries, an automobile parts supplier in Grand Rapids, Mich., explains plant operation to teacher-intern Peter Haverkamp

has increased the number of fellowships it grants at the graduate level. Several other companies have taken similar steps to augment scholarships and fellowships in areas in which shortages of scientists and engineers are now developing.

During the past 15 years, industry has joined in several partnership programs that are aimed at increasing the numbers of undergraduate and graduate majors in science and engineering. Most of these programs are directed at minorities. One of the oldest efforts is the National Consortium for Graduate Degrees for Minorities in Engineering (known as the GEM program). Begun in 1976, it is a partnership of 55 science and engineering schools and 65 corporations and independent research labs. So far, it has provided scholarship support to more than 900 minority students in engineering at the master's degree level. Recently, GEM announced two new efforts. One is a fellowship program for minority students who wish to pursue doctoral degrees in the sciences, and the other is a similar program for doctoral degrees in engineering.

Dennis J. Kreil, Ph.D. recruiting manager for Dow Chemical and vice president of science programs for GEM, says: "There is a real need for fellowship support for minority students in graduate education. When you look at the population of students graduating each year with Ph.D.s, you can see that minorities such as blacks, Hispanics, and American Indians are vastly underrepresented."

GEM Ph.D. fellowships cover all tuition and fees, fund annual stipends for five years, and provide salaries from summer research internships with sponsoring employers. Applicants must be U.S. citizens who are black, Puerto Rican, Mexican-American, or American Indian. In 1990, 25 fellowships for each of the Ph.D. science and engineering programs will be provided, and 40 will be given for each of these programs annually thereafter. In addition, about 150 M.S. engineering fellowships are given each year. Mentors are provided for the fellowship recipients at both the university and sponsoring company.

Another partnership that may help attract undergraduate and graduate students to science and engineering is the Presidential Young Investigators (PYI) program. Jointly sponsored by NSF and corporations, it provides research support to about 200 young faculty members in engineering, math, and all of the physical and life sciences, as well as behavioral and social sciences. According to Terence L. Porter, director of the research career development division at NSF, the primary goal of the program is "the recruitment and retention of high-quality young Ph.D.s in academic careers." It grew out of a concern that the best and brightest Ph.D.s were leaving academia for higher paying jobs in industry, thereby depriving the next generation of scientists and engineers of first-rate professors.

Young faculty who are chosen to participate in the program receive an annual grant of $25,000 from NSF and up to $37,000 more in annual funds if they are matched by contributions from corporations or nonprofit institutions.

Although the major goal of this program concerns faculty, one probable secondary effect is that it enables academic departments to recruit more students. A strengthened department with brilliant, in some cases well-known, instructors is likely to attract more graduate students and sometimes more undergraduates.

One aspect of the program that has shifted somewhat from what was planned originally is the lower emphasis on teaching. "From the beginning, this program was envisioned as having an important teaching emphasis. After all, we were putting in place the key teachers of the next generation of advanced scientists and engineers," says Porter. However, the program today seems to have little to do with teaching. NSF says only that a PYI award should not change the normal teaching requirement of the affected faculty member and that potential as a teacher is one qualification for nomination.

The PYI program may act as a double-edged sword in its effect on recruiting more undergraduates into science and engineering. The greater prestige a department gains from having young faculty members in the program may help in recruiting. But the time participating faculty members must spend soliciting matching funds and the great emphasis the program puts on their research may detract from the participants' effectiveness as teachers.

Industry supports, at least in part, a large variety of programs at the precollege level that are aimed at encouraging and preparing young people to major in science and engineering. Many of these are partnerships between industry, universities, and, in some cases, government. L. Sandy MacLean, vice chancellor for student affairs at the

Schoolchildren in Midland County, Michigan, use scales donated by Dow

University of Missouri, St. Louis, estimates that there are at least 200 such programs. In addition, individual companies, or sometimes industrial organizations, also carry on independent precollege programs to accomplish the same purposes.

Over the past two years, NSF has funded, or is about to fund, in cooperation with industry about 46 partnership projects that aim to improve precollege science and math education and increase the supply of scientists and engineers. Industry's "huge pool of skill and knowledge in technical areas constitutes a resource which can be, if used appropriately, a tremendous asset in improving science and mathematics education," says Charles R. Eilber of the education directorate at NSF.

One of the cooperative projects NSF is involved in is the Bridge program. In addition to NSF, it is funded by the state of Missouri, Union Electric, Monsanto, and Ford Motor. Students from five high schools in the St. Louis area participate in the program. The project has several components: college visits for the high school students; an academy at the University of Missouri that 50 high school students attend each Saturday for enrichment courses in science and math; a summer science academy at the University of Missouri involving 97 students; a combined credit program in which high school students earn high school and college credits simultaneously; a summer link program in which 50 high school seniors or recent graduates take summer courses at the university and are provided with jobs in the afternoon; and tutoring programs in all five high schools.

Students tour Monsanto's John F. Queeny plant in St. Louis

Another partnership called the RET-E^3 program works with elementary and secondary teachers rather than students. It is directed by the Coalition for Excellence in Science and Math, based at Grand Valley State University in Allendale, Mich., and sponsored by NSF, the coalition, Grand Valley State University, cooperating school districts, and businesses and industries. The program has several phases. First, outstanding science and math teachers are honored and most of them participate in a summer work internship in industry, where they learn some of the skills and technologies that are needed to be successful in a business organization.

As a part of the internship, the teachers investigate career opportunities for students and the skills and knowledge students need to foster during their secondary and college education. Afterward, the participants develop in-service training workshops to share what they have learned with other teachers.

Lester Wallinga, science teacher at Calvin Christian Junior High in Grandville, Mich., expresses the satisfaction that many of the teachers feel about their internships: "I experienced the revolution that is going on in industry. I saw the automated machines, the computer-assisted 'everything,' and the very evident pride of some of the older workers as they showed me their new high-tech skills."

According to David O. Tanis, executive director of the coalition, the RET-E^3 program provides teachers an opportunity to be inside an industry, revitalizes them, and enables them to develop new curricula. The program also benefits companies. "It helps industrial personnel understand problems in education in a new light," he says.

Last year, six Ohio companies, precollege teachers, and university teachers formed a partnership coordinated by Miami University chemists John P. Williams and Arlyne M. Sarquis. In the 1988–89 school year, 72 teachers from grades four through 12 and science coordinators participated in three industrial workshops. With lectures, laboratory, and discussion, the teachers were taught general principles of industrial chemistry, as well as the specific chemistry used by the six participating companies. They were instructed in activities and experiments they could use in their classrooms by industrial chemists and by university faculty. Then the teachers spent one day on site at one local company. After each session, the teachers tried out in their classrooms one or more of the activities they had been taught.

Good communication was established between the participating teachers and the mentors from industry and the university, which helps the teachers in their classrooms, Williams says. "A much larger number of teachers will be affected by the program as workshop graduates conduct training workshops within their own school districts," he notes.

The Partners in Science program is another effort aided in part by industry whose main purpose is to encourage talented young people to major in science. Coordinated by the Liberty Science Center and Hall of Technology, a new museum of contemporary science and technology in Jersey City, N.J., the program consists of research internships for high school students. This past summer 34 high school seniors spent seven weeks doing research. Seven students were assigned mentors in industry and 26 had mentors at universities. The students also attended biweekly seminars at the Liberty Science Center. The students found that personal contact with their mentor was the most important aspect of the program, says Dana Levine, outreach coordinator for the Liberty Science Center.

So far the program seems very successful. All of the 18 students who participated in the summer of 1988, the first year of the project, are now enrolled in college and 17 intend to major in science or engineering. This project is funded by the Geraldine R. Dodge Foundation.

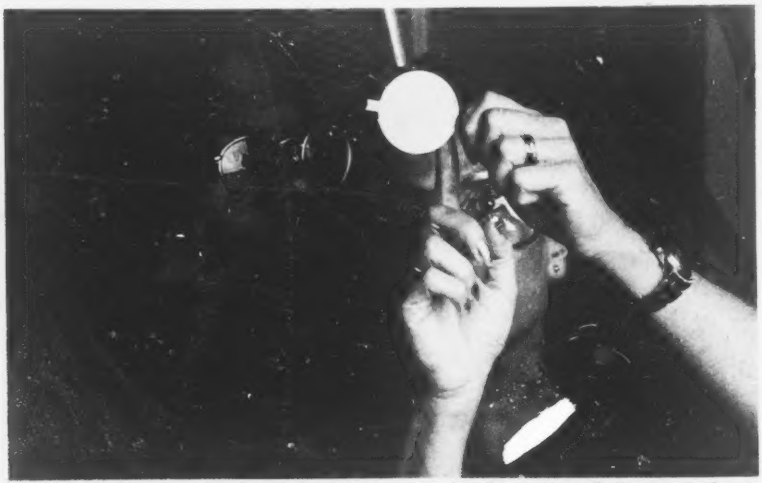
Companies also have been cooperating to produce instructional materials to be used in science classes across the country. One such effort, the Science Screen Report, is a series of videotapes and accompanying teachers' guides for classroom use in junior and senior high school. Seven videos are made each year concerning topics in chemistry, physics, biology, medicine, the environment, engineering, and other technological subjects. The series is underwritten by about 300 corporate sponsors, many of which are chemical companies, who donate the programs to schools in the communities where they operate. Currently, the series is used in about 5000 schools in nearly 2000 communities.

Chemical Education for Public Understanding Program (CEPUP) is another partnership effort to develop innovative science curricula. It is operated as part of the Lawrence Hall of Science at the University of California, Berkeley, and supported by NSF and a large number of major donors, including Arco Foundation, Chemical Waste Management Inc., Chevron Chemical, Dow Chemical, Hewlett-Packard, IBM, Shell Oil Foundation, and Union Carbide. The curriculum materials developed by CEPUP are specifically targeted toward helping students and the general public gain an understanding of chemicals and how they fit into society. Each curriculum module uses six to 10 hands-on activities to integrate the study of chemical concepts with societal issues. The modules are made for use both in middle school and in community education.

Many chemical companies have independently become involved in a wide variety of programs to improve science education. One such company is Monsanto. In addition to its support of the Bridge program, Monsanto participates in a large number of educational projects, most of them in the St. Louis area. For example, a Monsanto grant enabled the Mathematics and Science Education Center to begin developing biotechnology curriculum materials for children and adults and to start instructing teachers in the use of the materials.

Monsanto also participates in Inroads, a nonprofit organization that aims to interest precollege and college minority youth in engineering, science, and business. As a part of the program, Monsanto sponsored 22 minority student interns in the summer of 1988. The company supports a similar program called Horizons, which offers summer employment for minority high school students who are interested in careers in math and science.

In addition, Monsanto gives college scholarships in a novel way. The company contributes surplus equipment to colleges, which then offer scholarships equal to the value of the donated equipment.



Honors student from Detroit's Renaissance High School is taught by researcher during eight-week internship at Dow Chemical's Michigan division

Monsanto contributes significantly to the science fair for school-age children in St. Louis by providing financial, scholarship, and volunteer support. John L. Mason, president of the Monsanto Fund, which manages and finances most of Monsanto's educational programs, says, "We can imagine no investment with a greater return—for Monsanto or for the country—than education and, particularly, science education."

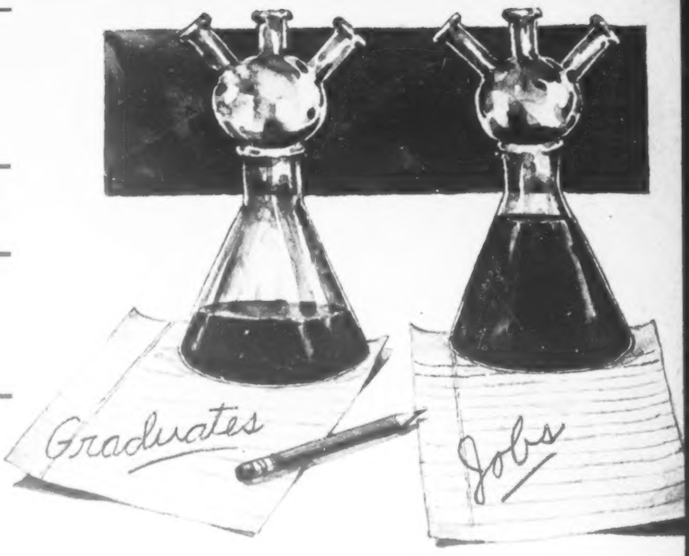
Dow Chemical is another firm that is involved in a large number of programs to improve science education on the precollege level.

Each summer, Dow sponsors 15 honors students from Detroit's Renaissance High School for eight weeks of research and engineering activities at the company's Michigan division. Students are assigned college-level projects that relate to their interests under the direction of Dow scientists, who serve as mentors and counselors. The students also are offered college scholarships. So far, most of the participants in the program have enrolled in college with majors in science, math, or engineering.

Another of Dow's projects is an entertaining, informative chemistry lab at Lansing's Impression 5 Science Museum. Dow built the lab and supplied it with the materials and staff to operate it. Opened in 1986, it provides a variety of demonstrations and workshops for school classes and the general public.

Dow also has contributed equipment for use in science classes to every public school in Midland County and instructs elementary and intermediate teachers on the effective use of the equipment.

The programs industry has initiated to improve precollege science education are so new it is impossible to judge their impact. However, the great number and variety of these programs indicate that industry is aware of serious problems in science education and that many companies are willing to invest both time and money to try to change the situation. □



Demand

The employment market for chemical professionals was stronger this year than at any time in the past decade

Demand for chemical professionals, strong in 1988, is even stronger this year. For chemical engineers, especially at the B.S. and M.S. levels, in fact, there appears to be a supply-demand crunch, which shows no signs of abating. Recruiters for the chemical industry report that the situation is not a crisis now, but could become one in a year or two.

Some chemistry department spokesmen also characterize the industrial job market as "excellent." In general, they say, demand is higher in 1989 than it was last year.

Chemical engineering department spokesmen report an even rosier picture from the graduates' perspective. Jobs outnumber candidates by a wide margin, they say. "A seller's market" and "excellent to overwhelming" are phrases they use.

The College Placement Council's July college recruiting survey also reflects high demand for chemical professionals. Except for M.S. graduates in chemistry, the numbers of offers for both chemists and chemical engineers at all degree levels rose markedly from July 1988. B.S graduates in chemistry received almost twice as many offers as of last June 6 than they received by the same date in 1988. Chemical engineers with a B.S. degree received 54% more offers. Similarly, Ph.D. chemistry graduates had 14% more offers, and those with a Ph.D. in chemical engineering about 50% more.

Figures from the latest ACS employment clearinghouse at the ACS national meeting in Miami Beach indicate high demand for chemical professionals as well. According to Joan E. Wheeland, coordinator for ACS employment and career services, which operates the ACS National Employment Clearing House, there were 601 positions posted but only 469 candidates there. In all, about 2600 interviews were arranged. From the job seekers' point of view, this was the best clearinghouse ACS has had in at least 16 years. It was also unusual, Wheeland says, because a very large number of postdoctoral positions were listed. Because postdoctoral positions are often a second choice for graduating Ph.D. chemists who can't find a job in industry or academia, a substantial rise in open postdoctoral positions usually indicates that more of these candidates found satisfactory work elsewhere.

An unusual combination of circumstances has led to this situation in which an ample supply of jobs exists for both chemists and chemical engineers. First, by most measures, the economics of the chemical industry were extremely favorable in 1988 and in the first half of 1989. In 1988, U.S. output of all types of chemicals was 8% higher than the year before, and earnings of major chemical companies rose 67% compared with a 52% increase in 1987. Capital spending in the chemicals and allied products industry was up 17% and outlays for research and development rose an estimated 12%.

Output so far this year, moreover, is running 7% above that of a year earlier. R&D spending is rising further. However, earnings growth slackened off in the first half of

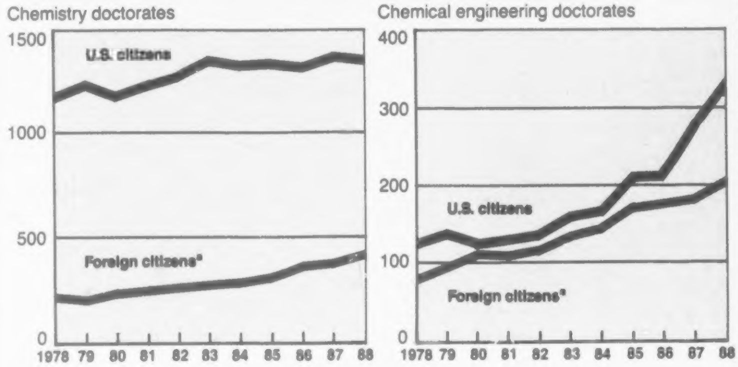
Bachelor's degrees in chemistry have declined in past decade, while Ph.D. degrees climbed

Academic year	Degrees awarded in chemistry			Degrees awarded in chemical engineering		
	Bachelor's	Master's	Ph.D.	Bachelor's	Master's	Ph.D.
1977	11,322	1775	1571	3581	1086	291
1978	11,474	1892	1525	4615	1237	259
1979	11,643	1765	1518	5655	1149	304
1980	11,446	1733	1551	6383	1271	284
1981	11,347	1654	1622	6527	1267	300
1982	11,062	1751	1722	6740	1285	311
1983	10,746	1604	1746	7145	1304	319
1984	10,704	1667	1744	7475	1514	330
1985	10,482	1719	1789	7146	1544	418
1986	10,116	1754	1908	5877	1361	446
1987[a]	9,661	1738	1976	4983	1184	497

a Preliminary figures. **Source:** National Center for Education Statistics

1989. For major chemical companies, earnings in the second quarter were only 3% higher than in the same period last year. But, profit margins are still predicted to be about the same as in 1988, and industry spokesmen are optimistic about the outlook for the year as a whole.

Ph.D.s in chemistry and chemical engineering earned by foreign students have doubled in past decade



[a] Students on temporary visa. **Source:** Doctorate Records File, National Research Council

Coincident with the healthy economy was an estimated further decline in the supply of newly graduating chemists and chemical engineers at both the B.S. and M.S. levels in 1989. Although the number of chemists and chemical engineers graduating at the Ph.D. level probably increased slightly, the number of Ph.D. chemists who are U.S. citizens fell. Therefore, the supply of new entrants into the chemical profession of all types and at most degree levels declined in 1989, and it is predicted to continue falling for a few more years.

High demand has had several effects, some routine and expected, but others that are almost unheard of in the hiring of chemical professionals. As usually happens in such a situation, starting salaries for both chemists and chemical engineers are up. However, the way in which they rose is rather unusual this year. Salaries offered to newly graduated candidates in the spring of 1989 were nearly $2000 to $3000 higher than offers in the fall of 1988. Usually, when a salary schedule is set in the fall, it remains fairly constant throughout the school year. This year, as the economy remained strong over the course of the school year and companies had more and more difficulty finding enough candidates, salaries escalated.

A second, more unexpected effect was that a number of companies began giving bonuses, ranging from $1000 to $10,000, to new graduates who accepted job offers. Some bonuses were awarded to Ph.D. graduates in chemistry; many more were given to chemical engineering graduates at all degree levels, but especially to those with a B.S. Such bonuses have several different names: sign-on bonus, report-to-work allocation, relocation fee, early decision bonus, special house-hunting bonus. All are a form of one-time compensation offered only to new hires. Some depend on the number of weeks the candidate takes to accept an offer. At least one Texas-based oil company gave $3000 if its offer was accepted in one week, $2000 at two weeks, and only $1000 if the candidate took three weeks to decide. Nearly all spokesmen from academia and industry contacted by C&EN had heard about such bonuses. Pharmaceutical and oil companies are mentioned most often as having engaged in this practice, but some chemical producers are also said to have awarded such one-time compensation to at least some of their new hires.

"Some companies are having difficulty hiring people. So to gain a competitive edge, they become involved with some one-time cost approaches," explains Fred O. Schulz Jr., manager of hiring for B.S.- and M.S.-level candidates in research and product development at Procter & Gamble. According to Rebecca J. Simon, placement director at the school of chemical sciences at the University of Illinois, "Companies are worried about such signing bonuses," because it partially undercuts their ability to recruit new employees. She points out that it is important to distinguish between bonuses and traditional recruiting strategies such as scholarships and summer hires.

Another related effect of high demand is that candidates have been bidding one company against another for salaries. Bidding has always happened to some degree, but seems to be much more widespread this past year. One company offers a salary to a graduating student and a second company makes a higher offer. The student then asks the first company if it can match or beat the second offer. The practice, according to one spokesman from academia, "is creating real problems for relations with current employees" because the new employee may be hired at a higher salary than those who have been employed for one or two years. Many industrial recruiters, however, say they never hire new employees at salaries that match or exceed those of existing employees because it would create severe personnel problems.

A final result of high demand is that companies are now considering whether in the next year or two they may need to employ more foreign graduates who do not have permanent residency status in the U.S. If a firm can prove to the Immigration & Naturalization Service that it has need for a candidate with particular skills and cannot find one who is a U.S. citizen or has a permanent visa, the company can legally hire a foreign graduate with only a temporary visa. Until now, most companies have not made the considerable effort required to go through this procedure. "So far we have tried to avoid that issue. It's so time-consuming and expensive. But if we can't find these skills in the domestic work force, sponsorship is a logical option," says William F.

Dausses, director of employment and placement for Phillips Petroleum. "The lack of domestic candidates for special needs will probably make sponsorship a part of normal business," he adds.

Chemistry department spokesmen at some major universities offer glowing reports of the job market for their graduates. Carole B. Moody, assistant director of student services in chemistry at the University of Michigan, Ann Arbor, says she had "three times more offers this year than last for B.S. candidates," even while the number of graduates stayed the same. She doesn't know of any Michigan chemistry candidates at any degree level who couldn't find a job. The number of recruiters on campus was "up slightly," with oil companies playing a somewhat larger role in the hiring picture.

Audrey L. Aylesworth, placement coordinator in the chemistry department at the University of Wisconsin, Madison, believes the job market for B.S. chemists is not quite that outstanding. She characterizes it only as "pretty good." However, chemistry Ph.D.s at Wisconsin were extended many more offers than the year before. In the 1988–89 school year, there were 26 unaccepted offers, whereas in 1987–88, there were only 10. Ph.D. candidates who took industrial positions averaged three offers each compared with 2.6 last year.

Four of the Ph.D. graduates at Wisconsin went directly to college or university teaching positions without first doing a year or two of postdoctoral work. To obtain an assistant professorship immediately after earning a Ph.D. was "unheard of five years ago," Aylesworth says. From this she concludes that demand for chemistry faculty must be high right now.

The University of Illinois' Simon found the industrial job market for chemists at all levels about the same as it was last year. For B.S. chemical engineering graduates, however, 1988–89 was far better. They received 148 offers, compared with 113 the year before. "Companies were complaining about not finding enough B.S. chemical engineering candidates. They'll be complaining more next year," she predicts.

Firms are now beginning to realize that "hiring a fairly consistent number of new graduates each year is a wiser business strategy," because it helps avoid the boom-bust cycle that discourages students from majoring in chemical engineering, Simon observes. She also notes that "oil companies are back much more in force than they had been" and quite a few new companies are recruiting. "Mergers are no longer having a negative effect on hiring," she says.

"In academia, it's thick and heavy," she adds. "The nation's faculty is aging. I think we have a serious problem in finding enough faculty," she comments.

R. Bryan Miller, chairman of the chemistry department at the University of California, Davis, found the job market excellent for B.S. candidates. "We had contacts from quite a few places that are looking really hard for B.S. people," he says. For M.S. and Ph.D. graduates, demand "seemed better this year than last, and last year was good." Almost everyone graduating from his department has found a position, he notes.

He, too, believes competition in the academic market is very keen. "I think that's only going to increase as time goes on in light of the predicted replacement of a very large percentage of current faculty in the next 10 to 15 years," he says. "One of the real problems I foresee is meeting the demand for Ph.D. chemists from both academia and industry."

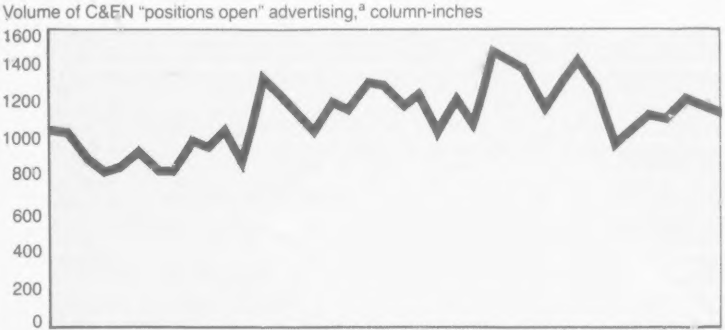
Steward J. Strickler, associate chairman of the chemistry department at the University of Colorado, also notes that, as far as he knows, all the chemistry graduates in his department found jobs. "There were several recruiters who came to the department seeking candidates for available jobs but couldn't find anyone to interview," he says.

Chemical engineering departments report even stiffer competition among companies for their graduates. William L. Conger, head of the chemical engineering department at Virginia Polytechnic Institute & State University, Blacksburg, says B.S. graduates there received four or more offers each, with some of them offered positions before Thanksgiving, which is unusual. He also notes that starting salaries kept escalating over the year. All the M.S. and Ph.D. candidates who wanted a job succeeded in finding one, he says.

One reason Conger gives for increased demand is that oil companies have started to hire again. "They are a significant influence on the market," he says. He claims that some companies gave sign-on bonuses to new graduates.

At Texas A&M University, Daniel T. Hanson, job coordinator for the chemical engineering department, also observed stiff competition for B.S. graduates. "I am fairly sure there are more jobs for B.S. chemical engineers than there are students available to fill them," he says. He believes the major reason for the high demand is the short-

Help-wanted ads have declined since last winter



[a] Column-inches published during consecutive periods of four weeks each; no issues were published in last week o December 1986, 1987, and 1988.

age of B.S. candidates. In 1989, Texas A&M had the lowest number of B.S. graduates since 1966. However, the freshmen class this year is larger. "I suspect this is partly due to the excellent offers at entry levels," he explains. As a consequence of high demand, some chemical and petroleum firms are giving sign-on bonuses, Hanson says.

Ronald Darby, professor in the chemical engineering department at Texas A&M, believes that one reason for the strong demand this year is the large number of jobs being offered by companies that design and build chemical plants.

Most industry spokesmen say that they hired more chemical professionals at all degree levels this year than in 1988, mostly because of expansions in plant capacity and in research.

Dausses of Phillips Petroleum says his company hired "10% more chemical professionals across the board" in part because of plant modifications and expansions Phillips has under way. Dausses believes that one explanation for the strong demand for B.S. chemists may be the shortage of chemical engineers. In some cases, "recruiters were trying to fill those positions with chemists," he explains.

He calls the strong 5 to 10% increase in starting salaries "really surprising." It is causing what he terms a "compression" problem—salaries for new hires "start dominoes moving up the organizational ladder, forcing companies to consider adjusting salaries of workers already on the payroll."

Robert K. Armstrong, manager of professional staffing at Du Pont, reports that his company hired fewer Ph.D. chemists than it did the year before, about the same number of B.S. and M.S. chemical engineers, and more Ph.D. chemical engineers. However, he found the job market competitive for all these categories, but especially for B.S. and M.S. chemical engineers. As a result, there is more talk about bargaining for salaries this year, he says.

In contrast, job openings for chemical professionals at Dow Chemical are up substantially this year, says James E. Townsend, manager of recruiting programs. The number of B.S. chemists hired was up 20 to 25%, Ph.D. chemists up 100%, B.S. chemical engineers up 30%, and Ph.D. chemical engineers more than 100%. The new job opportunities at Dow arose mainly because of expansion in facilities and strong business conditions. "We're hearing a lot of rumors about signing bonuses and report-to-work allowances," Townsend says. "But we haven't heard anyone actually say they are giving bonuses."

Union Carbide also has had an increased need for chemical professionals this past year. According to Thomas J. Neelen, manager of professional staffing, about 15 to 20% more B.S. and M.S. chemical engineers were hired, primarily because Carbide is expanding facilities around the country. "We filled the majority of our openings, but recruiting would have been considerably easier if the supply had been greater and there hadn't been so many other companies looking for so many B.S. chemical engineers."

Even though Procter & Gamble hired fewer chemical engineers this past year, P&G's Schulz found competition intense. "Unless we have a recession, we could easily be moving into a tight scene—not necessarily a panic scene, but a tight scene," he comments.

College placement personnel, department heads, and industrial recruiters believe that demand for chemical professionals next year will be just as high or even higher. Most add that a recession could change the situation markedly, but they don't expect an economic downturn.

The University of California's Miller thinks that, barring a recession, demand for B.S. and Ph.D. chemists will remain strong. Aylesworth of the University of Wisconsin also thinks the job market for chemists next year will be about the same as it was this year. Already the schedule of companies who have signed up to interview students is fairly full, she says.

Simon of the University of Illinois says, "We're going to have a full house this fall. It looks terrific. I expect hiring will be up this year, especially for B.S. chemical engineers."

Industry spokesmen express concern about finding enough candidates of the caliber they want. Carbide's Neelen expects the job market next year will be "just as competitive. Recruiting will be at the same level, if not greater, and shortages will still exist, particularly in chemical engineering."

Dausses of Phillips Petroleum expects that the market for chemists and chemical engineers "will be very hot." Demand at his company will be up another 10% and the number of graduates will be down, he says. Dow Chemical's Townsend expects that demand will be "at least as good as in 1989, if not a little bit better. I expect to see pressure and competition next year for chemical engineers." Schulz of Procter & Gamble expects that the job market for chemical engineers will be "tighter this coming year than it was last year. I think that some companies that don't have salary or location advantages will not find satisfaction. As a consequence, they are going to either go with a chemical engineering graduate who is not as strong as they want, or go with a substitute degree, or they're going to pay extra money."

Overall demand for chemists, as shown in the column-inches of help-wanted ads in C&EN, was slightly higher in the past 12 months than it was in the previous 12 months. However, in 1989, the volume of advertising did not reach the peak that it attained in September 1988.

Unemployment figures for chemists who are members of ACS are at historically low levels. As of March 1989, the overall unemployment rate was 1.0%, the same as it was in March 1988. The rates for all categories, whether minority or nonminority, male or female, at all degree levels are close to 1%, about as low as they have ever been since ACS initiated employment surveys in 1971.

The ACS starting salary survey also compiles unemployment rates for newly graduated chemists and chemical engineers as of last June. These data, too, reflect high demand. For Ph.D. chemists, the unemployment rate dropped from 11% in 1988 to 6%. For chemical engineers with a bachelor's degree, the rate fell from 8% to 7%. ☐

Salaries

For newly graduated chemists and chemical engineers, starting salaries are higher at all degree levels

Starting salaries followed the same trend as demand for chemical professionals this year. They are up for both chemists and chemical engineers at all degree levels, but did not rise as much as might be expected from the increased demand.

According to a recent ACS survey, the median salary of inexperienced M.S. chemists changed the most. It jumped 13% from $27,700 in 1988 to $31,200 this year. (However, last year's median had been essentially unchanged from the year before, while those for both B.S. and Ph.D. graduates were higher.) The median salary for B.S. chemists went up 6% from $21,900 to $23,200, but for Ph.D. chemists, it rose only 4% from $40,500 to $42,000.

The changes in chemists' starting salaries over the past year are consistent only with what has happened over the past decade for chemists with a bachelor's degree. Salaries for inexperienced B.S. chemists advanced at an average rate of about 5% per year between 1979 and 1989, almost the same as the change between last year and this year. In contrast, starting salaries for both M.S. and Ph.D. graduates increased about 6% per year over the past decade, very different from the 13% and 4% changes that occurred this year.

When adjusted for the 5% inflation rate, the median starting salary for M.S. chemists still took a large jump, 8% over that in 1988. The median for B.S. chemists, however, rose only 1% and that for Ph.D. chemists declined 1%. Since 1979, the changes in starting salaries after adjustment for inflation have been mixed. The median starting salary for B.S. chemists has declined 4%, the median for M.S. chemists has increased 10%, and that for Ph.D. chemists has risen 9%.

For more than a decade, starting salaries for chemical engineers with a bachelor's degree have been much higher than salaries for inexperienced B.S. chemists. The difference this year is 43%, the same as it was in 1988.

Unlike last year, when starting salaries of chemical engineers at all degree levels did not even advance enough to keep up with inflation, the median salary of B.S. chemical engineers increased 6% to $33,000, the salary for chemical engineers with a master's degree rose 9% to $36,000, and that for engineers with a Ph.D. degree climbed 6% to $47,000.

These data were collected by the ACS Market & Business Analysis Department from 3500 respondents to a survey of chemistry and chemical engineering graduates. However, because salaries at most degree levels escalated markedly over the course of the school year (about $2000 to $3000, according to anecdotal information), the results of the survey, which are medians for the entire school year, are probably lower than the medians for only those students hired late in the school year—in June, July, and August, for example. Last year salaries were more stable over the course of the school year. Therefore, the percentage changes from last year to late summer this year may actually be greater than the ACS survey indicates.

In the late 1970s and early 1980s, inexperienced women chemists earned more than their male counterparts. In 1983, the situation reversed and median starting salaries for male chemists became greater again. This year the salary differences changed again. At the B.S. level, women earn $24,000 at the median, 4% more than men. However, at the M.S. and Ph.D. levels, men continue to earn more than women. Men with a master's degree earn $32,000, 23% more than women, whereas men with a Ph.D. degree earn $42,000, only 1% more.

Inexperienced male chemical engineers with a bachelor's degree earn $33,000 at the median, 1% more than comparable women. At the M.S. and Ph.D. levels the number of women who responded to the survey is so small that significant comparisons cannot be made.

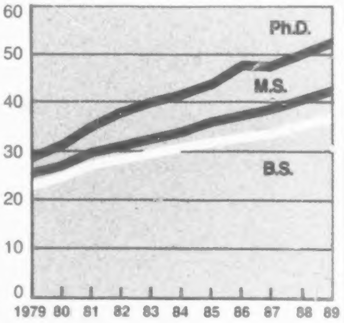
In private industry, the starting salaries for male chemists at the M.S. and Ph.D. levels are higher than those for comparable women, but at the B.S. level the median starting salary for men is lower than that for women. B.S. women graduates started with a salary of $26,000, 8% higher than the $24,000 for men. Men chemists with a master's degree earn $32,000, 7% more than the salary for women. At the Ph.D. level, the median starting salary for men at $43,650 is 4% more than the $42,000 for women.

As usual, inexperienced chemists who choose to work in private industry earn more than they do in almost any other sector. For example, inexperienced Ph.D. chemists earn a median salary of $42,950 in industry, whereas those employed by a college or university earn only $27,000. Inexperienced chemical engineers also seem to have higher median salaries in private industry than they have in other sectors, but the number in other sectors who responded to the survey is too small to be significant.

Of those chemists who graduated with a bachelor's degree, about 52% plan to pursue advanced full-time studies in the fall of 1989. In contrast, only 20% of the B.S. chemical engineering graduates intend to study full-time in the fall.

Salaries of experienced chemists rise steadily...

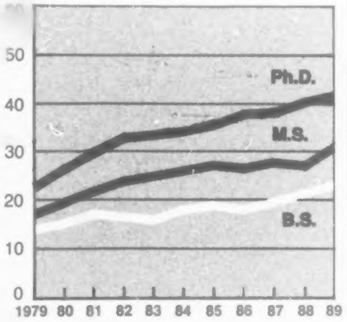
Median annual salaries of experienced chemists, $ thousands



Note: Data as of March of each year.
Source: ACS annual surveys

...while those for new chemists also are higher

Median annual salaries of inexperienced chemists, $ thousands



Note: Data as of the summer of each year.
Source: ACS annual surveys

Of those B.S. graduates in chemistry who plan to pursue full-time advanced studies in the fall of 1989, 39% will study chemistry and an almost equal number, 32%, will study medicine. Other fields that B.S. chemists have chosen for advanced study include biochemistry (9%), dentistry (3%), pharmacy (3%), and chemical and biochemical engineering (1%). In contrast, almost three quarters (71%) of the B.S. chemical engineering graduates who plan to pursue advanced full-time studies will be taking courses in chemical or biochemical engineering. Medicine, at 7%, is the B.S. chemical engineers' second highest choice and other engineering, at 6%, the third. Undergraduate work in chemistry is used much more than chemical engineering as a stepping stone to careers in other fields.

In contrast to salaries of inexperienced professionals, the salaries of more experienced chemical professionals advanced only moderately this year. According to a survey of about 12,000 ACS members completed in March, median base salaries for chemists, at all degree levels, are only 5% higher than they were last year. This advance was just enough to keep up with inflation, which was 5% from March 1988 to March 1989. These changes in salaries are almost the same as those that occurred last year, when the median salary of B.S. chemists rose 6%, and those for M.S. and Ph.D. chemists both rose 5%.

Similarly, during the past decade salaries of chemists at all three degree levels have remained fairly constant when adjusted for inflation. The median salary of B.S. chemists has declined slightly, and the medians for M.S. and Ph.D. chemists have increased only slightly.

In contrast to the salaries of inexperienced chemical engineers, the median salaries of more experienced chemical engineers in industry remained fairly flat. For Ph.D. chemical engineers in industry, the median was $64,700 compared with $62,900 last year (up 3%). Chemical engineers with a master's degree earned a median salary of $53,000 compared with $50,900 last year (up 4%), and B.S. chemical engineers earned a median salary of $47,700 both this year and last. None of these salaries advanced enough to keep up with inflation.

The gap between salaries for men and women chemists remains about the same as it has been for the past few years. When women's salaries are adjusted for the differences in average length of experience between them and men, the mean (rather than the median) salary for Ph.D. women chemists in industry is only 87% of the mean for men. In academia, women earn 17% less than men. At the B.S. level, the differences are even greater. In industry, women chemists with a B.S. degree earn 15% less than comparable men chemists.

One reason women's salaries are lower than men's is that women are much less likely than men to hold supervisory positions. Therefore, when the salaries of those chemists who earned their B.S. degrees less than 10 years ago are compared, the salary differences are much smaller because relatively few chemists hold a supervisory position after only a few years of work. For Ph.D. chemists in industry who earned their B.S. degree less than 10 years ago, the median salary for women, $45,000, is almost identical to that for men, $44,800.

For Ph.D. chemists, overall salaries in industry remain higher than those in academia. In private industry, the median salary is $58,000 compared with $43,000 in academia. But the median salary of Ph.D. chemists working for Ph.D.-granting schools is $54,900, much higher than the overall median for academia.

Industrial chemists' salaries vary greatly depending on the industry. Ph.D. chemists who work in the petroleum and natural gas industry have the highest mean salary, $69,500; the next highest mean salary is in the pharmaceutical industry, $64,900. B.S. chemists in the basic chemicals, plastics, and electronics industries have the highest mean salaries, about $46,200. (These means have been adjusted for differences in average length of experience of chemists for each group.) □

Data corrected for CPT annual report

Owing to an anomaly in the computer program, most of the totals for bachelors, masters, and doctorates in chemistry and chemical engineering are incorrect in the tables accompanying the ACS Committee on Professional Training 1988 annual report (C&EN, June 19, page 93). Totals of the individual schools are correct, but the grand totals in many instances are incorrect. The corrected tables appear below.

Corrected reprints of the 1988 CPT Annual Report are available from the Office of Professional Training, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036.

Summary of data from approved schools, 1984–88

	Bachelors				Masters		Doctorates	
	Number of schools	Graduates (totals)	Certified graduates	Noncertified graduates	Number of schools	Graduates	Number of schools	Graduates
CHEMISTRY								
1984	577	9819	4201	5618	321	1637	189	1777
1985	579	9679	4021	5658	316	1621	186	1806
1986	580	9295	3892	5403	315	1620	187	1885
1987	582	8848	3663	5185	316	1636	188	1936
1988	584	8372	3453	4919	319	1584	192	1955
CHEMICAL ENGINEERING[a]								
1984	120	6866	6866	—	114	1436	101	357
1985	123	6442	6442	—	118	1489	104	418
1986	118	5229	5229	—	116	1244	103	460
1987	107	4435	4435	—	103	1078	90	533
1988	128	3524	3524	—	124	1036	106	603

[a] Chemical engineering departments are not required to report their data to CPT, so the number of departments included in this category varies from year to year.

Summary of totals from 1988 reports from approved schools

	Schools reporting	Men	Women	Total
CHEMISTRY				
Bachelors, Total	584	5077	3295	8372
Certified		2116	1337	3453
Noncertified		2961	1958	4919
Masters	319	1054	530	1584
Doctorates	192	1504	451	1955
CHEMICAL ENGINEERING				
Bachelors,				
Certified	128	2612	912	3524
Masters	124	850	186	1036
Doctorates	106	526	77	603

More tours information for PACIFICHEM '89

The following list of tours planned for Wednesday, Thursday, and Friday at PACIFICHEM '89 in Honolulu, Dec. 17–22, was inadvertently omitted from the Final Program of the meeting, Oct. 2 issue of C&EN:

WEDNESDAY, DEC. 20

GP-18. 8 AM to 5 PM. Special Tour: Share the Tradition. See GP-8 for details. Cost: $53. Minimum 20.

GP-19. 8:30 AM to 12:30 PM. Special Tour: a Monarchy Day Revisited. See GP-2 for details. Cost: $17. Minimum 30.

GP-20. 8:30 AM to 12:30 PM. Special Tour: a Camera Buff's Historical Tour. See GP-3 for details. Cost: $16. Minimum 30.

GP-21. 9 to 11 AM. Native Hawaiian Crafts. See GP-11 for details. Cost: $5.00.

GP-22/adult; GP-22c/child. 12:25 to 10:30 PM. Polynesian Cultural Center Tour. See GP-12 for details. Cost: $49 adult; $25 child. Limit 100.

GP-23/adult; GP-23c/child. 1:15 to 5:45 PM. Mini Circle Island/Sea Life Park Tour. See GP-7 for details. Cost: $27 adult; $23 child. Limit 100.

THURSDAY, DEC. 21

GP-24/adult; GP-24c/child. 6:16 AM to 7:30 PM. One-Day Tour to Maui. Fly to Kahului, then drive to the top of the Haleakala Crater, 10,000 feet above sea level. See rare silversword and the state bird nene. Continue to Iao Valley and Old Lahaina Town, once the capitol of Hawaii's kingdom. Stop for lunch (cost not included). Price does include roundtrip transfers in Honolulu, airfare, and admissions to Haleakala National Park, and tour on Maui. Cost: $120 adult; $99 child. Limit 50. *Advance registration required.*

GP-25. 9 to 11 AM. Native Hawaiian Crafts. See GP-11 for details. Cost: $5.00.

GP-26/adult; GP-26c/child. 8:45 AM to 12:30 PM. Arizona Memorial Excursion. See GP-4 for details. Cost: $13 adult; $10 child. Limit 100.

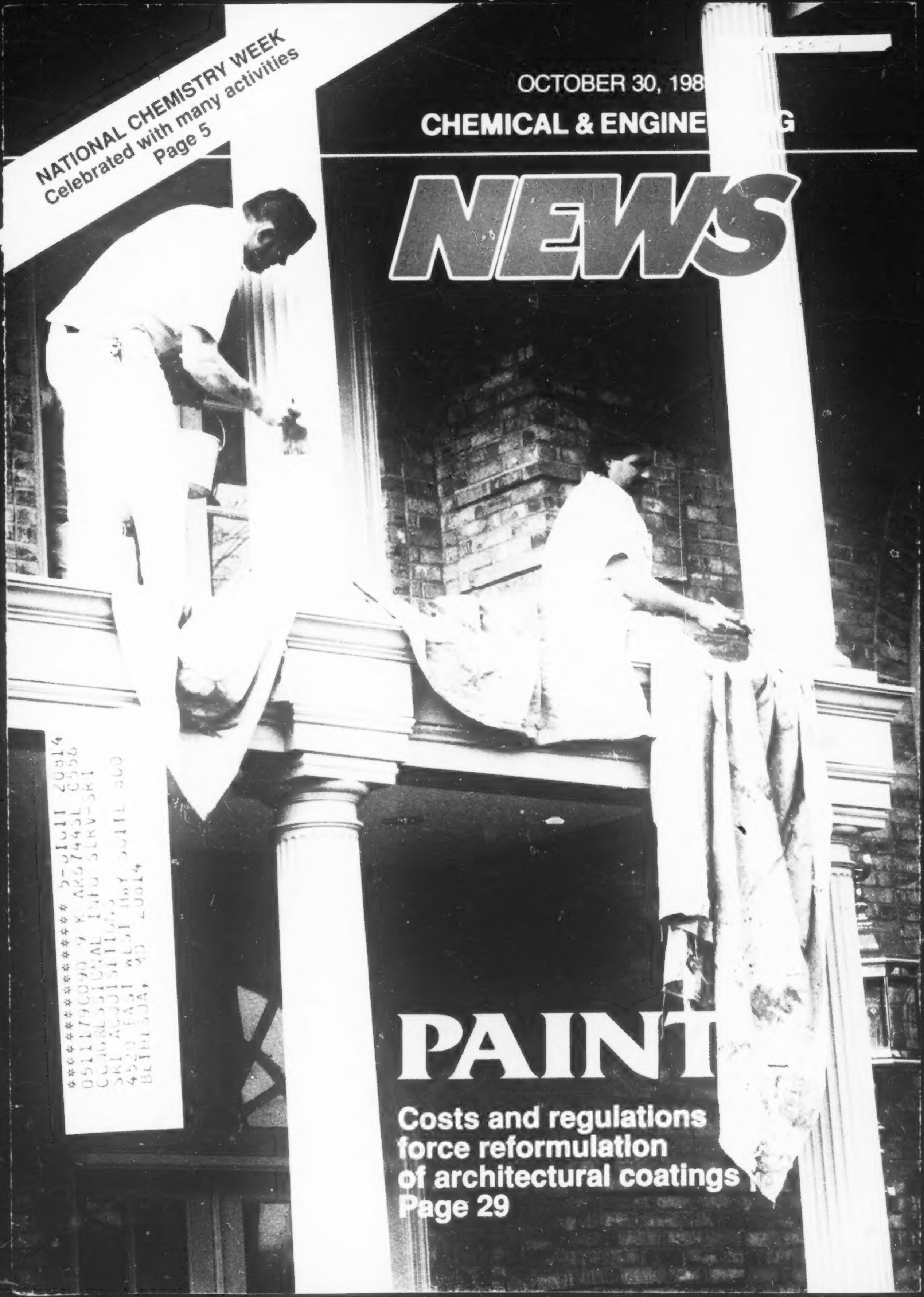
GP-27/adult; GP-27c/child. 1 to 5 PM. Scenic Honolulu City/Dole Pineapple Cannery Tour. See GP-17 for details. Cost: $16 adult; $12 child. Limit 100.

FRIDAY, DEC. 22

GP-28. 8 AM to 5 PM. Special Tour: Share the Tradition. See GP-8 for details. Cost: $53. Minimum 20.

GP-29. 8:30 AM to 12:30 PM. Special Tour: a Camera Buff's Historical Tour. See GP-3 for details. Cost: $16. Minimum 30.

GP-30. 9 to 11 AM. Native Hawaiian Crafts. See GP-11 for details. Cost: $5.00.



OCTOBER 30, 198

CHEMICAL & ENGINE G NEWS

NATIONAL CHEMISTRY WEEK
Celebrated with many activities
Page 5

PAINT

Costs and regulations
force reformulation
of architectural coatings
Page 29

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CHEMICAL & ENGINEERING
NEWS

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OCTOBER 30, 1989

News of the Week

- **The huge explosion and fire last week at Phillips 66's Pasadena, Tex., plant killed and injured scores of people, took out of commission one of the world's largest polyethylene facilities.** Page 4
- **After months of planning, ACS's National Chemistry Week is under way with a variety of activities around the nation.** Page 5
- **Participants in House hearing condemn awarding of performance bonuses to contractor at Department of Energy nuclear arms plant, despite environmental, safety, and health violations.** Page 5
- **A new drug of abuse, a smokable form of methamphetamine called "Ice," is racking Hawaii and experts fear it will become the "drug of the '90s."** Page 6
- **Chemical industry faces cyclical downturn after long string of earnings gains, as several firms register third-quarter declines.** Page 6

Business

Some signs of an economic slowdown are worrying European chemical industry executives, although their mood is still generally upbeat. **Page 9**

Government

Senate's reconciliation budget kills number of provisions sought by chemical industry and ACS, including R&D tax credits. **Page 14**

Alternative fuels and alternative-fueled vehicles are focus of study to be conducted jointly by nation's largest automakers and 14 major oil refiners. **Page 17**

Science/Technology

Silicon microphysiometer developed by Molecular Devices Corp. gives sensitive measures of metabolic responses of cells. **Page 20**

Great Lakes ecosystem needs immediate cleanup action according to recent study. **Page 22**

Booklet on values, conduct of scientists produced by National Academy of Sciences in effort to provide professional context for graduate students, faculty members. **Page 24**

This year's measurements of Antarctic ozone hole indicate depletion matches record set in October 1987. **Page 24**

Books

"High Tech Holocaust" eschews abuse of modern technology, but provides little vision or direction for readers. **Page 65**

Cover: Photo courtesy of Porter Paint Co.

Letters 2
Editor's Page 3
Concentrates
Business 7
Government 12
Science/Technology 19
The Departments
New Products 57
Meetings 69
Newscripts 88

Product Report

Architectural paints continue to make up nearly 50% of all paint shipments, but environmental regulations and raw material costs are forcing manufacturers to search for ways to reformulate them. **Page 29**

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LETTERS

CHEMICAL SAFETY

Sodium nitrite

SIR: We narrowly averted an explosion in our heating and cooling plant due to the improper use and disposal of a fire extinguisher agent and an oxidizer called Vaporene N-90. The oxidizer, packaged in a polyethylene bag-lined, standard open-head 300-lb-size fiberboard drum, is used for corrosion control in a recirculating, chilled-water system. Workers were removing metal pipe hangers when a piece of hot metal ignited the drum. The worker on fire watch had difficulty extinguishing the fire and used two 20A120BC dry chemical extinguishers. Workers cleaned up the fire scene by placing the spent fire extinguishing agent and the remains of the Vaporene drum inside a larger fiberboard drum. We noticed that the drum felt unreasonably warm and suspected that a chemical reaction was taking place within the drum. The drum of material was removed from the building, and the contents were hastily separated and quenched with water.

After the fire had been extinguished, we checked the material safety data sheet (MSDS) for Vaporene N-90 and found that it is composed of sodium nitrite and sodium tetraborate and is incompatible with ammonium salts. The label on one of the fire extinguishers listed its contents as ammonium phosphate. The second extinguisher's contents were determined by calling the manufacturer and requesting an MSDS. The MSDSs for both extinguishers did not list incompatibility with sodium nitrite. The explosive danger of sodium nitrite was demonstrated at Berkeley (C&EN, Oct. 11, 1982, page 29) where 3 lb did $200,000 damage.

Mark T. Jensen, *Microbiologist*
Steve Rod, *Safety Technician*
Department of Agriculture
Ames, Iowa

Communication challenge

SIR: Ann Thayer's cover story, "Alar Controversy Mirrors Difference in Risk Perceptions" (C&EN, Aug. 28, page 7), addresses an issue that will profoundly influence how billions of taxpayer's dollars will be spent in the future. Two important factors relative to how we approach this issue were not addressed in the article.

The article stresses the importance of the role of industry and government in communicating more effectively with the public about its perception of chemicals in the environment. We in academia must also share in this responsibility. Indeed, our involvement is essential. The academic membership of the Council for Chemical Research is taking an active role in this arena and there are signs that the American Chemical Society is beginning to do likewise.

The article acknowledges that the public can be very much influenced by the media and refers to the "60 Minutes" segment on Alar that aired May 14. What the article does not state is that the media can grossly distort scientific arguments as was done with the material presented from Ed Bradley's interview with Bruce Ames on this "60 Minutes" segment. For many Americans, programs like "60 Minutes" are biblical truth—as are pronouncements made by admired performers such as Meryl Streep. Communicating with the public under these circumstance is a real challenge.

Fortunately, all is not lost. One of the media world's most trusted personalities, Walter Cronkite, has just completed a superb television tape, "Big Fears, Little Risks" (Film Counselors, NYC), which attempts to present a rational discussion of risk assessment. The public may not listen to the presidents of ACS and Du Pont, but they do listen to Ed Bradley and Meryl Streep. Fortunately, they will also listen to Walter Cronkite.

J. Ivan Legg
Dean, College of Sciences and Mathematics
Auburn University

Arms control negotiations

SIR: Regarding the recent pronouncements of progress toward the reduction of the chemical weapons stockpiles of the U.S. and the U.S.S.R. (C&EN, Oct. 2, page 6), it is useful to remember that the 80% reduction generously offered by President Bush is already required under Public Law 99-145. This law requires that the Department of Defense destroy most of the U.S. stockpile by 1997. To this end, technology demonstration and prototype work are currently under way at Johnston Atoll and Tooele Army Depot.

That the President could use a mandated unilateral stockpile reduction to induce the Soviets to make their own cuts may reveal something of the nature of superpower arms control negotiations.

David N. Clark
Plain City, Ohio

European Execs Grow Concerned Over Outlook for Chemical Industry

Although generally optimistic about 1990s, speakers at marketing research meeting see worrisome signs, question how long before a downturn

Patricia L. Layman, C&EN London

The mood at this year's annual meeting of the European Chemical Marketing Research Association, held earlier this month in Paris, was essentially upbeat. But that nagging question—how long can the good times last?—had become strong enough to give the meeting a more reflective atmosphere than in the past few years.

Bernard Azoulay, vice president of international operations for Atochem, the chemicals arm of France's Elf Aquitaine group, set the stage in his keynote speech. "The chemical industry has enjoyed an exceptionally long and profitable cycle, something that the historians may call one day the roaring '80s of the chemical industry," he said. "But now, everybody in the industry is concerned because of some worrying signs which appeared during the last months, and particularly the sharp decrease of the prices of some commodity chemicals."

As he saw it, the crucial question is whether the chemical industry will be able to cope with the slowing down or recession of the European economies, and minimize the impact on its profitability. "From what we have seen during the last months, particularly the erratic variations of the prices of some chemicals, we are not really prepared for that," he argued.

The general outlook for the 1990s is actually quite favorable for the industry. According to Kjell Andersen, special economics adviser to the Norwegian delegation to the Organization for Economic Cooperation & Development, Western European economies will grow at an annual rate of 3 to 4% for the 1990s, a bit more than in the past 15 years. Japan's economy will continue to grow 4% or more per year, and the U.S.'s, about 3% per year.

Moreover, oil prices—increases in which hurt the chemical industry in the mid-1970s to the early 1980s—look to be stable into the next decade. That was the forecast of Silvan Robinson, chairman of the energy and environmental program of the Royal Institute of International Affairs, London.

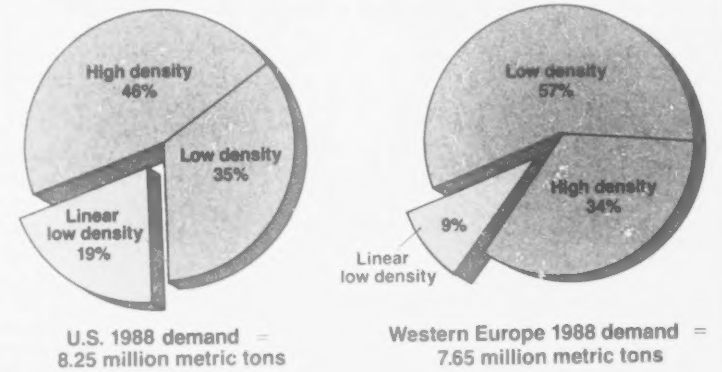
Rising demand could force oil prices to rise, he conceded. But environmental questions, which "will dominate the agenda for the oil industry in the next 10 years," probably will curtail demand to the extent that supplies won't be pushed enough to justify price hikes.

Instead, key to the industry's performance over the next few years, Atochem's Azoulay and other speakers agreed, is the specter of overcapacity in several important chemical industry products.

Azoulay cited ethylene as an example. Cracker capacity in Western Europe is expected to climb from the current level of just over 14 million metric tons per year to about 20 million metric tons by the year 2000. If there is sustained strong economic growth, he predicts, production by that year would amount to about 18.5 million metric tons and capacity use to 92%. However, if Western European economies were to slide into recession, production would be only about 15 million metric tons per year and capacity use a nonprofitable 75%.

Polyethylene consumption also has climbed markedly in the past few years. The polyethylene market in Western Europe is just slightly smaller than that in the U.S.—7.65 million metric tons in 1988, compared with 8.25 million metric tons in the U.S. The product mix in Eu-

Linear low-density polyethylene accounts for 19% of market in U.S., only 9% in Western Europe



Source: Atochem

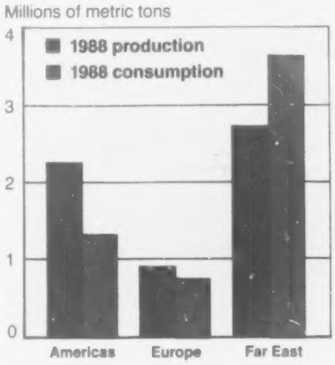
rope hasn't shifted so much as that in the U.S., where linear low-density polyethylene accounts for nearly one fifth of the market, perhaps because European producers have been preoccupied with restructuring and slashing capacity. Low-density polyethylene continues to dominate the West European market, pointed out Philippe Goebel, director of polyethylene for Elf Aquitaine Group's chemicals unit, Atochem.

"Over the next two years, I am not pessimistic," said Pierre-Yves Masson, president of London-based Shell Chemicals International Trading Co. "There won't be a big drop in most commodity petrochemicals. After that, however, I'm very concerned." Of the announcements of new crackers to be built, he added, "there is more than a 50% chance that these plants will be built. If we go into a recession, then we will go into the same position as in the early 1980s."

Polypropylene and terephthalic acid also were cited as having the potential for significant overcapacity by speakers at the meeting. Forecasts for polyvinyl chloride, on the other hand, showed its capacity as tracking closely with consumption through the end of the decade.

True to the theme of the conference—strategies for world markets—speakers agreed that these problems in overcapacity would be global. However, Masson pointed out, although Western Europe in the year 2000 "will remain a net exporter of petrochemicals and polymers," its share of chemicals trade is shrinking. Many of its traditional customer countries, such as those in Southeast Asia, are building their own capacity. And other countries have become or are working to become strong exporters, in competition with European producers.

Far East use of terephthalic acid outstrips production



Source: Amoco Chemicals, Europe

GE dominates sales of engineering, high-performance plastics

Millions of metric tons, 1988	GE Plastics	Hoechst	Bayer	Du Pont	BASF
Americas	315	75	70	135	20
Europe	125	155	140	45	140
Asia/Pacific	70	95	15	30	15
TOTAL	510	325	225	210	175

Source: Hoechst

Perhaps the best example of a newly emerged global competitor in the chemical industry is Saudi Arabia, under the aegis of Saudi Arabian Basic Industries Corp. (SABIC). In the early 1980s, SABIC disclosed its plans for the first phase of entering the chemical industry, plans that many in the U.S. and European industries discounted at the time.

However, results have been dramatic. SABIC, which now ranks itself as 25th in the world among petrochemical companies, has spent some $12 billion in a variety of plants and complexes. With SABIC accounting for the majority of Middle East production, the Middle East now accounts for 9% of world ethylene glycol capacity, 5% of ethylene, 5% of high-density polyethylene, and 4% of linear and conventional low-density polyethylene. The Middle East also accounts for 9%, 4%, and 5% of world capacities of methanol, ammonia, and urea, respectively, said Yousef Al-Zamel, director of chemical sales for SABIC Marketing Ltd. Most of the ethylene is used in downstream plants, he added, "to gain value-added products for use in local markets and for export."

In its next phase, SABIC plans to spend $4 billion on increases in capacity from debottlenecking, flexible-feedstock crackers, downstream derivatives, and fertilizer plants.

"Much of our effort in the next decade will continue to be in joint ventures with outside—possibly European—companies," added Al-Zamel. "We see Europe as an important market for our chemicals, but this should not become too heavily emphasized since our efforts will also concentrate on sales to our natural markets in the Middle East and Far East."

The Far East, in particular, remains a solid market for western petrochemicals, despite indigenous industry buildup. For example, according to John Umfreville, business development manager for Amoco Chemicals, Europe, the industry is seeing a buildup of capacity in terephthalic acid used to make polyester. Because some 79% of the 10.4 million metric tons of polyester consumed annually is used to make fiber, the primary market is the Far East, seat of the world's textile industry.

The building of terephthalic acid capacity in the Far East will inaugurate a period of global oversupply, Umfreville predicted. However, with demand growing for the acid at 6.4% per year between now and the end of the century, the Far East will continue to be a net importer of terephthalic acid because of continued investment in polyester capacity.

The markets for engineering and high-performance plastics, however, are predominantly in North America (37% of world demand) and Western Europe (34%). Japanese consumption accounts for 20% of world markets, and the rest of the world, 9%, said Dietrich Fleischer, manager for polymers R&D at Hoechst A.G. Not surprisingly, the major suppliers are U.S. and West German companies.

The annual growth rate of engineering plastics—including polyacetals, polyphenylene oxide, and polycarbonate—ranges from 5 to 10%. Those for high-performance plastics—such as polyarylate, polysulphone, polyether imide, polyether ketone, and liquid crystal polymers—are in the 15 to 25% per year range, he added. Global demand for both classes of these plastics was about 1.99 million metric tons in 1988, and is expected to reach nearly 3 million metric tons by 1995. ☐

PRODUCT REPORT

Demand Puts Paint Sales At Record Levels

Glidden/ICI Paints photo

Marc S. Reisch,
C&EN Northeast News Bureau

Increased demand again put paint sales at record levels as producers shipped more than 1 billion gal of paint and coatings in 1988 valued at more than $11 billion.

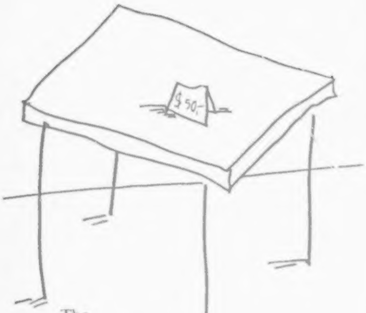
An analysis of government statistics providing a profile of the paints and coatings industry follows beginning on page 30. Those statistics show that though architectural paints continue to make up nearly 50% of all paint shipments, they represent only 40% of the value of all paints and coatings shipped.

Manufacturers of architectural coatings, the focus of C&EN's examination of the paint market beginning on page 37, are under increasing government pressure in busy metropolitan areas to reduce the volatile organic compounds (VOCs) contained in their coatings formulations. Partly as a result, alkyd paints have become increasingly less important in architectural coatings. However, there may be new life in alkyd coating systems. Recent research into a natural reactive diluent derived from the seed of an African plant, *Vernonia galamensis*, promises to permit the formulation of alkyd coatings that contribute virtually no VOCs as they cure.

Beginning on page 50, the growing problem of the rising cost of formulating and labeling products (especially when the prices of many of the raw materials going into low-profit-margin architectual paint rise faster than consumer prices of paint) is explored. Not enough paint retailers agree with Robert E. Champagne, president of Porter Paint and chief executive officer of Courtaulds Coatings N.A., who says, "Consumers can't afford to buy less than the best. But the industry has been in the business of selling cans of paint and not the product they contain. That has done a lot of damage."

Rohm & Haas is now trying to focus do-it-yourselfers on more expensive, quality paints via its Paint Quality Institute. But though some would like to see architectural paint quality and the prices that consumers willingly pay increase, many in the industry doubt whether that will happen soon. Paint formulators continue to look for ways to cut cost.

Beginning on page 54, the role of colorants and additives in cutting costs is examined. Paint makers can reduce their costs and also get a consistently good product by depending increasingly on color dispersant manufacturers for color-



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ants rather than making their own. And should the emphasis on quality increase and prices in general rise for architectural coatings, industry suppliers are ready with a number of additives to improve paint quality and performance.

Shipments up 3.7% last year

U.S. paint makers shipped close to 1.1 billion gal of paints and coatings in 1988, according to the Department of Commerce. That volume of shipments marked a strong 3.7% increase over the previous year for an industry that more frequently turns in 1 to 2% annual growth rates. In terms of value of shipments, the industry did much better in 1988. The value of shipments rose 10% to $11.1 billion in 1988 compared with the previous year.

Increases in shipment values, however, must take into account the rise in raw material prices that paint makers had to pass along to consumers in 1988. The Department of Labor's producer price index showed that paint materials prices increased 7.8% in 1988 compared with 1987. Clearly then, the increase in shipment value can't have gone entirely into the paint producer's pocket.

Overall, then, the paint industry's performance pretty much parallels that of the U.S. economy, whose gross national product grew at a constant dollar rate of 3.9%, according to the Department of Commerce.

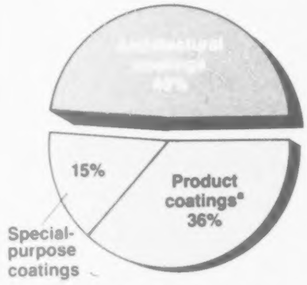
This year, however, promises to be slower overall. Shipments for the first six months of 1989 at 640 million gal have lagged the comparable period of 1988 by 2.1%. Some industry observers cite wet weather in the Northeast as a reason for a decline in exterior architectural and maintenance coatings sales for 1989. But the value of shipments of these coatings increased 6.4% during this period, again mainly because of raw material price increases that have been passed along to the consumer.

As increases in raw material prices continue to put pressure on paint makers, and as changes in the regulatory environment, particularly in relation to volatile organic compounds, add more pressure, the industry continues to contract. Strong regional and national manufacturers have the edge. According to Stephen Einhorn of Einhorn Associates, Milwaukee, Wis., the competitive balance is shifting in favor of the larger firms.

Two of the larger acquisitions to take place this year, Whittaker's coatings and chemicals division by Sherwin-Williams for $147 million and Reliance Universal by Akzo for $275 million, represent about 10% of the $4.5 billion industrial product coatings market, notes Einhorn. He figures that the strategy of many of the larger paint producers is to improve market share even though earnings are barely satisfactory. In the long term, he says, they do expect above average earnings.

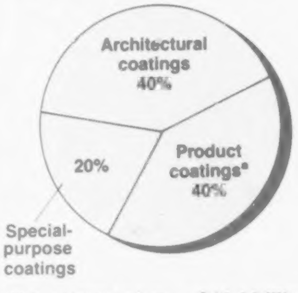
Other acquisitions that have taken place this year include Courtaulds' $282 million purchase of Product Research & Chemical, a sealants and high-performance coatings manufacturer, Dainippon's purchase of resin producer Spencer Kellogg,

Architectural coatings dominate shipments…



Total 1988 shipments = 1.09 billion gal

…equal product coatings in value of shipments



Total 1988 value = $11.1 billion

[a] Original equipment manufacturers.
Source: Bureau of the Census

32

Nippon Oil & Fats' $25 million purchase of the U.S. paint division of Grow Group, and the $16.5 million purchase of Whittaker's Ram division by Lilly Industrial Coatings. Recently PPG Industries announced plans to purchase Olympic and Lucite from Clorox for $130 million. Kline & Co., the Fairfield, N.J., consulting firm, says its worldwide acquisition tracking service lists 25 paint and coatings combinations in the period between January and July 1989.

The number of U.S. paint producers continues to decline, according to James A. Rauch of Rauch Associates, Bridgewater, N.J., which produces the Rauch Guide to the U.S. Paint Industry. In 1967, 1459 companies produced paint; in 1982 there were about 1170 paint producers. Today he suspects the number is closer to 900. Mergers and acquisitions activity within the paint industry over the past 10 years has accelerated, both Rauch and Einhorn point out. Both agree that the number of active paint formulators will continue to contract.

Two major reasons for the large number of mergers and acquisitions are the increase in paint ingredient costs and the cost of reformulating and relabeling to conform to conflicting local government regulation. Other reasons include intense industry competition, low profit margins in many but the most specialized applications, and globalization efforts by some large paint makers as they purchase smaller companies and thus increase market share. Another factor is the continuing interest by foreign paint producers in securing and increasing their U.S. market share while the dollar is still attractively priced and the U.S. government is not intervening in acquisitions by foreign-based operations.

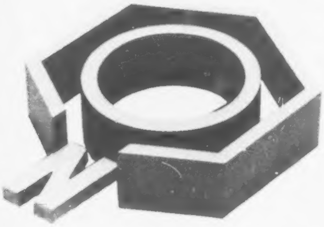
A 1988 profile of the industry based on Bureau of the Census figures shows that architectural coatings, which include both interior and exterior house paints, continue to make up almost half of all paint sold in the U.S. Product coatings for the original equipment market (OEM), which includes automotive and appliance coatings, accounts for some 36% of U.S. paint volume. And special-purpose coatings comprise about 15% of total paint shipments. This category includes large-volume maintenance items, automotive refinishing, and coil coatings.

Shipments of architectural coatings in 1988 increased 0.9% to 532 million gal. The value of those shipments, however, rose 3.8% compared with the previous year to $4.38 billion, and the unit price per gallon rose 2.7% to $8.23. Architectural coatings shipments showed some resilience in 1988 despite the decline in housing starts and new housing units put in place for the year.

Product coatings shipments for the OEM sector rose again in 1988, up 2.1% from 1987 to 393 million gal. The value of those shipments rose 16% from the previous year and the unit price increased 11% to

PRODUCT PROSPECTUS

Pyridine
and Derivatives



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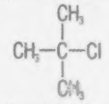
Alkylchlorides

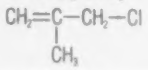
n-Butylchloride
(1-Chlorobutane)
$CH_3{-}CH_2{-}CH_2{-}CH_2{-}Cl$

tert.-Butylchloride
(2-Methyl-2-chloropropane)



$$CH_3{-}\overset{\displaystyle CH_3}{\underset{\displaystyle CH_3}{C}}{-}Cl$$

Methallylchloride
(3-Chloro-2-Methyl-
1-Propene)



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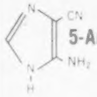
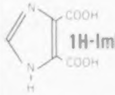
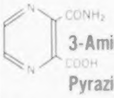
&
PYRAZINES



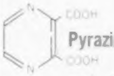
5-Amino-1H-imidazole-4-carbonitrile



1H-Imidazole-4,5-dicarboxylic acid



3-Aminocarbonyl-
Pyrazinecarboxylic acid



Pyrazine-2,3-dicarboxylic acid

and other derivatives

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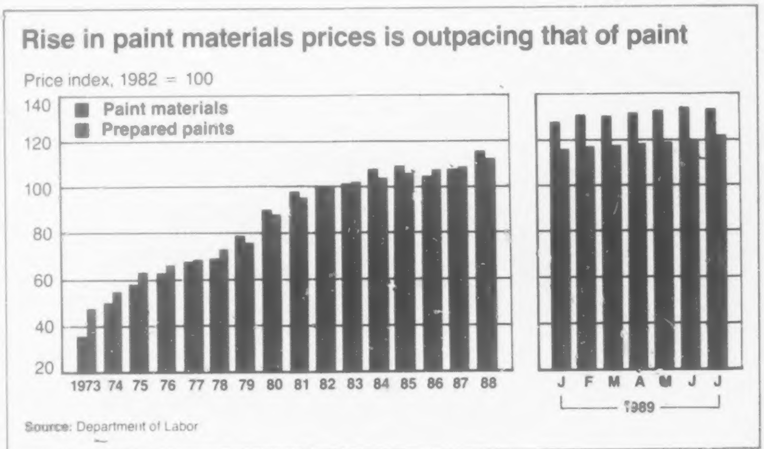
$11.35. A portion of that increase in shipment value and unit price may be related to higher U.S. passenger auto, truck, and bus sales in 1988. Automakers, as well as other OEM manufacturers, are bearing the cost of reformulated and, in many cases, higher solids paints, to bring their plant emission outputs into conformance with VOC regulations.

Special-purpose coatings shipments and total value also increased in 1988. According to government figures, special-purpose coatings shipments increased 19% compared with 1987 to 162 million gal. The value of those shipments year-to-year rose 13%. However, the unit price per gallon fell 5.4% to $13.77.

Some analysts question the veracity of data on the special-purpose category. They suspect that the price fluctuations are in part due to reporting confusion and inconsistency.

According to the Department of Labor, indexes covering both paint materials and prepared paint show that prices continued to rise in the first six months of 1989. The index for paint materials prices rose 4.4% to 133.0 (1982 = 100) between January and June, reflecting increases not only in the price of titanium dioxide, but also of solvents. In 1988 the index rose to 115.7, an increase of 7.8% over the previous year.

Prepared paint prices have not kept up with raw material price increases. Pricing is frequently viewed by the manufacturer as the key to a larger share of the market and thus greater profits. In a bid for greater share of market, paint makers often temper price increases even though raw material costs are rising faster.


Rise in paint materials prices is outpacing that of paint

Source: Department of Labor

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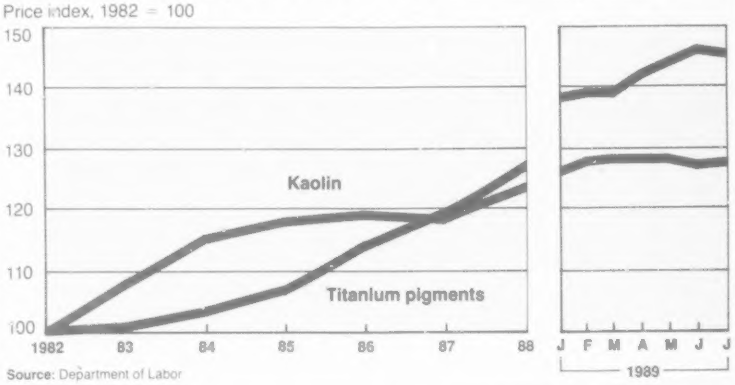
Titanium pigment prices rise faster than kaolin prices



Source: Department of Labor

Between January and July, the index for prepared paint prices rose 3.4% to 120.3, a full percentage point below the increase in the index for raw material costs. In 1988, the index for prepared paint prices rose to 112.2, 3.8% over 1987. That increase, passed along to paint consumers, was four percentage points below the increase in the index for raw material costs.

From 1973 to 1988, paint materials prices increased about 7.9% per year. Over the same period of time, prepared paint prices have risen about 6% annually. Consequently, if prepared paint prices don't increase, either raw material prices will have to drop or paints will have to be reformulated and quality may suffer.

To meet the increase in shipments of paint in 1988, paint makers hired more employees. According to Department of Labor statistics, the total number of production and nonproduction paint industry workers rose 1.4% last year to 63,500—the same level as in 1985—compared with 1987. Still, the industry produced 69 million gal more paint than in 1985. Over the years, the paint industry has been able to produce more paint even as the level of employment has declined. Between 1979 and 1988, industry employment declined 7.4%

The number of both production and nonproduction workers in the industry increased between 1987 and 1988. Nonproduction employees of paint firms rose 0.6% in 1988 to 32,100; production employees increased 2.3%. However, between 1979 and 1988, employment of production employees fell 13% to 31,400. The level of nonproduction employees during this period decreased only 3.1% to 32,100.

Architectural paints' plight

The architectural coatings market is frequently viewed as mature and unexciting, with low profit margins despite high volume. But it is a market that represents opportunity, or else PPG would not be interested in purchasing the Olympic and Lucite paint lines nor would Courtaulds have made its investment in Porter Paint a few years ago.

The architectural coatings market does have drawbacks. National hardware and discount store chains use paint sales as low margin loss leaders to generate sales traffic in their stores. In the process they accustom the consumer to expect unrealistically low prices for paint, says one industry observer. Some paint producers carry architectural paint lines as a way not only to leverage their fixed costs but also to give them raw material leverage when they negotiate supplies for their entire line.

Where architectural paint lines include solvents that contribute to VOCs, manufacturers have to put a great deal of money into reformula-

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ting their products to lower VOC emissions to meet standards set principally in California, but also in New York, New Jersey, and other states. Adding to the confusion is the host of differing standards issuing from a number of air quality management districts within each state.

California has a patchwork of air quality districts that generate regulations in concert with the state's Air Resources Board in Sacramento. The board's stationary source division advises the 41 air pollution and air quality management districts on standards for reduction in air pollution that would bring a district in compliance with federal air quality standards. According to an information officer for the board, 23 districts have adopted rules affecting architectural coating VOC limits and the rules can vary from district to district. Districts cannot adopt weaker rules than the benchmark standards the state board suggests, but the rules can be more stringent. Districts, he points out, can decide not to adopt any rules at all, and 18, mostly sparsely populated, districts have not adopted any standards.

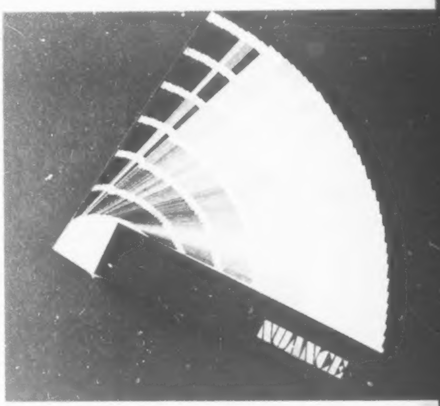
A technical document published by the Air Resources Board in July 1989 states that "statewide emissions from architectural coatings are estimated to have been 154 tons per day in 1984, which represents approximately 18% of all VOC emissions from solvent use sources in California. Architectural coatings are estimated to account for about 8% of all statewide nonvehicular emissions."

New state board standards put into effect in September by a number of air quality management districts have affected a category of specialty architectural coatings including enamel undercoatings, metal pigmented coatings, tilelike glazes, and others. These new standards would, says the state board, "reduce emissions from application of architectural coatings by about 9% in the year following adoption, and by an additional 5 to 13.5% in the fourth year after adoption. . . . These estimates are based on sales volume indicated in the 1984 Architectural Coatings survey. Since the coatings market in California has been growing, we believe actual reductions from 1988 sales volumes will be greater."

Most paint makers are confounded by the web of standards in effect. "We need uniformity for economy of scale so that research and development can be directed at achieving one and not a host of requirements," says Frederic J. Zimmerman, an attorney on the staff of the National Paint & Coatings Association.

Zimmerman says that paint manufacturers would like to see one set of national standards in effect. The opportunity to set national standards might be achieved in 1991 when the Clean Air Act comes up for reauthorization, he says.

Notes Bob Koch, vice president of trade sales for ICI's Glidden, some of the differing labeling standards required from municipality to municipality are confusing. It means contantly changing labels as new rules go into effect. "I'm for clean air, too," he says, but "these well-intentioned clean air efforts are killing us."



Huls photo

Fan deck of architectural coatings

To meet lower VOC emissions standards, Glidden, like most others in the paint industry, have gone in the direction of developing high solids and latex-based coatings. And Koch is confident that as technology develops, paint makers will be able to drive down VOC emissions. But the confusing web of regulations has forced the company to

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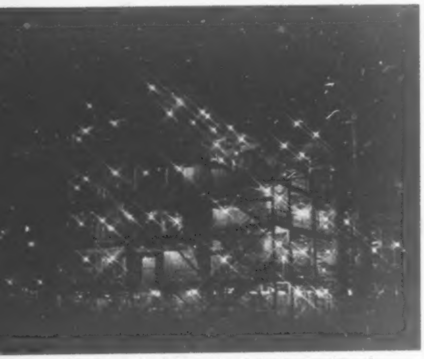

Du Pont's Altamira Ti-Pure titanium dioxide plant in Mexico

scramble in certain instances. Some Glidden products are now "localized" exclusively for California, he says, and that creates a host of problems. It forces the company to carry many more products in inventory, and thereby increases its costs.

Although Glidden is not against lowering VOCs in its paint formulations, it would prefer a national standard. "There is an opportunity here for us," says Koch. Because Glidden is part of ICI's worldwide paint and coatings business, it has access to technology that would give it a competitive edge. But that leverage could only be useful if it had a national standard to which it could formulate, says Koch.

Many paint companies are formulating their products with some of the California standards as a basis. Because the state's Air Resources Board has invested so much time and effort into developing regulations, many other states look to California for guidance. And the National Paint & Coatings Association as well as individual paint producers have begun to regard California's strict VOC paint regulations as the standard against which to formulate.

The California Air Resources Board's July 1989 technical document notes that "the primary source of air emissions from architectural coatings is the solvent component. Other ingredients in the coating may also volatize and be lost to the atmosphere but these emissions are generally trivial when compared to the solvent emissions." Reducing VOCs then takes any number of forms, including substituting mostly water reducible resins in applications where solvent and oil-type resins had been used formerly and using more active solvents to reduce higher solids paint.

In situations where coatings are applied by the consumer, as they are largely in the architectural paint classification, waterborne coatings have largely displaced solvent-based coatings. But most contractors still prefer solvent-based coatings because they can be applied over a wider temperature range, adhere better to older, chalky substrates, and are more resistant to abrasion. Where glossy finishes are preferred, oil-based formulations still predominate because they generally perform better.

Oil-based paint formulators may get a lift from recent research. According to Robert E. Perdue Jr., a taxonomic botanist recently retired from the Department of Agriculture's Agricultural Research Service, an oil derived from the seed of *Vernonia galamensis*, a plant native to Africa, can replace traditional solvents in alkyd resin paints. Based on estimated U.S. alkyd paint use of 325 million gal, paint formulated with vernonia oil could reduce VOC emissions by 20 million gal annually.

Vernonia produces seeds that contain oil, which, Perdue says, is chemically similar to epoxidized soybean and linseed oil. But unlike these oils, which are highly viscous, semisolid at 50 °F, and nonpourable below 32 °F, vernonia oil has a low viscosity and is pourable below 32 °F, he explains. As a result, vernonia has potential as a reactive diluent in alkyd paints and wouldn't, he believes, contribute any VOCs to the final paint formulation.

Eugene B. Schultz Jr., professor of engineering and applied science at Washington University, St. Louis, has begun some studies on the economic viability of vernonia oil. He describes the seed oil content as similar to that of the sunflower seed and, given existing technology, says that the extraction of the oil is not

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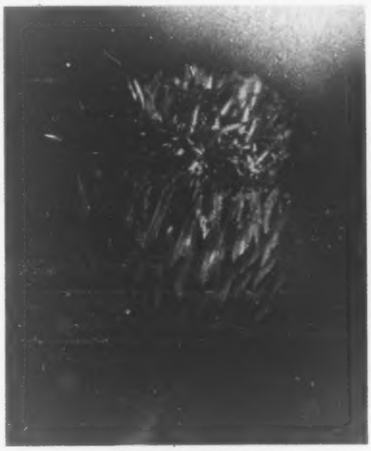
expensive. Because *Vernonia galamensis* is native to Africa and does best in semiarid tropical and subtropical regions, Zimbabwe and Kenya are the most likely areas to cultivate the plant initially.

Schultz says that the wild, unimproved germ plasm has already yielded 650 to 700 lb of oil per acre in test fields in Zimbabwe. Although it is difficult to put a cost on the oil, he believes it "probably won't be more expensive than sunflower oil."

The South Coast Air Quality Management District (SCAQMD) in California, which includes Los Angeles, has taken an interest in the potential commercialization of vernonia. The district is among the strictest in VOC standards and has put regulations into effect in advance of most other state districts. According to Larry Watkins, a program supervisor for stationary demonstration projects at SCAQMD, the district has contributed $190,000 to research in the potential commercialization of vernonia now under way at the Coatings Research Institute (CRI) of Eastern Michigan University in Ypsilanti.



USDA photos

Vernonia galamensis plant *(left)* may *provide oil for alkyd paints; in Africa, USDA's Perdue (above, left) inspects vernonia crop with chemist T. Nyati*

Watkins, a chemical engineer, calls the chemistry of vernonia oil "pretty sexy." He is particularly excited about it because SCAQMD sees it as a natural epoxy oil with no VOCs whatsoever. The real problem, he says, is that commercial quantities of the oil are not yet available. He sees no problem in obtaining the oil once it is produced in commercial quantities, because both Zimbabwe and Kenya have had fairly stable political climates for the past 15 years. Also, the plant has potential as a commercial crop in Colombia and Costa Rica, he notes.

Watkins thinks the oil will work in high-solids as well as low-solids alkyd formulations. He hopes that SCAQMD's funding of the CRI effort will result in the technology for paint makers to develop proprietary coatings. He says the project has no interest in developing technology to license paint formulators.

According to John C. Graham, director of CRI, a total of $425,000 has been committed for the two- to three-year research project not only from SCAQMD, but from the U.S. Agency for International Development, the state of Michigan, and Paint Research Associates, an industry-financed research authority that Graham also directs. Work already under way by a research team headed by Stoil Dirlikov, formerly of Dow Chemical and Case Western Reserve, along with two postdoctoral students and one graduate student, shows that vernonia is compatible with alkyd. The researchers hope to have more substantial information in the key area of VOC reduction within the next three to six months.

Until more is known about the performance of vernonia oil in paint formulations, paint manufacturers will have to tinker with their for-

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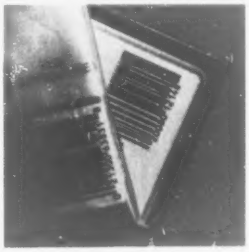

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mulations to meet changing regulations. According to Ernest A. Hahn, director of planning and development for PPG's coatings and resin group, new VOC regulations require continual modifications in the formulation of the company's product line in an effort to maintain the quality and performance levels the public associates with PPG's label. Supplying compliant products is "an expense that we have to absorb," says Hahn, to build PPG's long-term strategy in the architectural coatings market.

Hahn notes the move in architectural paints to waterborne solvents not only helps the company produce compliant formulations, but also is advantageous in the do-it-yourself paint market where easy cleanup is a selling point. He estimates that of all architectural coatings sold, about 80% are latex and 20% are solvent formulations.

One approach to lowering VOCs in solvent coatings is replacing common diluents such as mineral spirits, toluene, and xylene with 1,1,1-trichloroethane. According to James A. Mertens, Dow project leader in the chemicals and metals division, the company's trichloroethane solvent in some cases can substitute for common diluents on a one-to-one basis "at increased cost, but it does get the VOCs down."

But Mertens cautions that substituting with trichloroethane is only a short-term solution. Those paint makers who reformulate might find it more cost effective to produce high-solids products. He also is aware trichloroethane does contribute to stratospheric ozone depletion. Its contribution, he notes, is significantly less than chlorinated fluorocarbons, which are scheduled for commercial phaseout under the Montreal protocol.

In addition, trichloroethane may be classified as a toxic air contaminant. According to the July 1989 California Air Resources Board technical support document on architectural coatings, "Manufacturers may elect to use 'exempt' solvents such as 1,1,1-trichloroethane or other halogenated compounds to reduce the VOC content of their coatings to meet the new standards. . . . [But] some of these substances (e.g.

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Hahn: move to waterborne solvents

1,1,1-trichloroethane) may be reviewed for possible identification as toxic air contaminants. . . . Identification of a substance as a toxic air contaminant would almost certainly lead to its removal from architectural coatings."

To produce lower VOCs, paint formulators are turning to higher solids solvent coatings, and to do that they have adopted higher solvency power products. A spokesman for Eastman Chemical notes that "Eastman products such as methyl amyl ketone and methyl propyl ketone are used in compliance coatings because of their low weight per gallon and high solvency power." The Eastman spokesman also adds, "Acetylacetylation technology was introduced to the industry by Eastman and it should increase the resin manufacturer's ability to design resins for low-VOC coatings."

Du Pont is promoting its dibasic ester family of solvents for use in some solvent-based coating systems both because these solvents' slow evaporation rate "contributes less to the VOC problem," and because they are safer, low-toxic biodegradable solvents, notes J. A. Senex III, marketing manager in Du Pont's petrochemical department. Senex says that dibesic ester is also an ideal paint cleaner for use in brush and hand cleaning formulations and can be incorporated in paint removing formulations as a replacement for methylene chloride, a suspected car-

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cinogen. Senex describes the dibasic ester family as "almost a drop-in for acetone." He adds that, although it is more costly per pound than either acetone or methylene chloride, not so much dibasic ester is required in formulations in which it would displace these solvents.

Although VOC output in latex coatings isn't so great a concern as in solvent-based coatings, solvents are used in waterborne formulations. Eastman, for instance, has supplied latex paint formulators with its Texanol ester alcohol since 1962 and also markets Ektasolve EB glycol ether for use in architectural coatings as a coalescent for latex paints. Going up against Texanol is a new Exxon Chemical coalescent, Exxate 1000, that market development specialist Jackie Reynolds describes as a "pretty low-odor isodecyl acetate." Exxate 1000 will cost slightly more than Texanol, she says, but offers low odor, good freeze-thaw stability, and may require less product by volume than the Eastman agent, thereby resulting in lower unit cost. She adds that Exxate 1000 also promises to contribute fewer VOCs per unit of paint because it has low specific gravity and because it will be incorporated into paint formulations at lower concentrations.

Raw material costs on the rise

Increases in raw material prices this year also are creating headaches for paint makers. Notes a vice president in charge of purchasing for a major paint manufacturer, prices for hydrocarbon solvents have "yo-yoed" up and down as oil fluctuated between $11 and $23 per barrel this year. Prices of toluene, xylene, mineral spirits, and aliphatics have reached all-time highs during the year. Prices of titanium dioxide also reached new highs this year, though they have dropped back some. Titanium dioxide, admits one supplier, is now a "major part of paint cost aside from the can."

According to the U.S. Department of Labor, producer prices for titanium pigments increased 6.8% in 1986 from the year earlier; they rose 4.5% in 1987 and then 6.4% last year. Users had to pay an additional 5.1% for the pigment between January and July of 1989.

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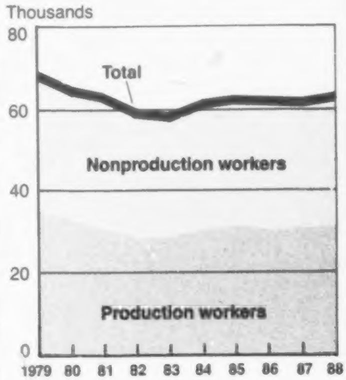
There is, however, no real substitute for titanium dioxide, says Sol Spindel. Spindel, president of New York City-based DL Laboratories, runs one of the few independent paint performance testing labs in the U.S. accredited by the National Institute of Standards & Technology. Titanium dioxide prices currently exceed $1.00 per lb, in contrast to 25 to 30 cents more than 10 years ago, he notes. Spindel says there is currently a lot of interest in technology to extend the usefulness of the dioxide in paints and he plans to chair a conference next spring on the subject.

Extender pigments have been used for years, but because of the current high price and continuing shortage of titanium dioxide worldwide, extenders such as talc, zinc oxide, and kaolin have generated more interest. "There is a variety of materials to extend TiO_2, but nothing to replace it on a cost performance basis," notes Spindel.

Prices of extender pigments also have been much more stable than those of titanium dioxide. The price of kaolin, for example, has increased only 1.2% between 1985 and 1986, according to the Department of Labor's producer price index. In 1987, the price of the processed clay product rose 0.5% compared with the year earlier, and was up 3.6% in 1988 compared with 1987. Although titanium dioxide prices continued to move up this year, kaolin prices have been relatively stable, rising only 0.8% between January and July 1989.

Over the past few years, the supply of titanium dioxide has been tight at any price. "During the last two years customers have been ordering TiO_2 months in advance just to get their allocation," notes Donald V. Borst, president and chief executive of SCM Chemicals, a titanium dioxide supplier. It is, he notes, the best opacifying agent available with the highest index of refraction of any white pigment. "Extender material can only be used to a limited extent," he notes. Mindful of the current price and supply situation, those who use extenders have to do so to get the most economical performance system. They "need to do their homework," he says, if the quality of a paint is to be preserved.

Employment edges up in paint industry



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Prices have increased and are likely to continue to rise, notes Borst, not just because of the supply situation. Prices are up also because of environmental controls that pigment producers must install at their plants and because of raw material price increases based on the cost of ilmenite ore, which itself must be mined so as to minimize environmental impact. The supply situation is expected to ease by 1994, however, as producers have announced new projects. SCM, says Borst, plans a titanium dioxide plant in Ashtabula, Ohio, at a cost of $67.5 million with an annual capacity of 58,500 tons for startup in 1991.

Borst suggests that with the growth of global paint producing companies, there will be a need for a consistent "world grade" of titanium dioxide to supply those companies who want to make similar paint products internationally. Multiyear contracts between producers of the dioxide and users could result in guaranteed supplies and prices for the paint formulators, says Borst. They would also guarantee a market for the dioxide producer and ore miner, both of whom could then project and amortize their investments in the titanium dioxide business with some degree of certainty.

"U.S. TiO_2 pricing is the lowest in the world," says a spokesman for Kerr-McGee's pigment division, whose Hamilton, Miss., titanium dioxide plant is rated at 106,000 tons. Higher prices overseas have led the company recently to export product for the first time. And, he adds, it will "continue to do so as the opportunity offers."

As for titanium pigment extenders, they have, admits the spokesman, filled some voids. But the extenders can only go so far. Kerr-McGee's spokesman believes they can replace, at most, only 10% of titanium dioxide.

Kaolin, contends Craig J. Stoneback, worldwide marketing director of Engelhard's pigments and additives division, is the best extender of titanium dioxide and other pigments. And William E. Nettles, group vice president and general manager of the same division, notes that Engelhard is working on new technology to extend color pigment with kaolin as well. The kaolin extender disperses titanium dioxide in a paint and improves the light scattering qualities of the dioxide, says Stoneback.

Engelhard, says Stoneback, is also providing a very fine grind kaolin to act as a titanium dioxide extender in solvent paint where traditionally the clay has not wet so well as in latex paint formulations. Prices of kaolin are more than competitive with other extender products and currently amount to 10 to 30 cents per lb. To supply paint and other markets with kaolin extenders, Stoneback says that Engelhard finished an $80 million, 300,000-ton expansion of its kaolin capacity last November.

Giving kaolin some competition as a titanium dioxide extender is an opaque polymer from Rohm & Haas called Ropaque. According to Patrick R. Colau, manager of Rohm & Haas' North American coatings business, Ropaque is a polymeric particle surrounding a water core. As the polymer dries, it leaves an air void in the center that translates into hiding power. Thus it can substitute for about 5 to 10% of the titanium dioxide in a paint formulation. Most of the opportunity for this extender is in the exterior flat paint market, says Colau. Ropaque is, he says, attractively priced relative to titanium dioxide.

Stoneback: kaolin the best extender

Use of colorants growing

In the area of color, Engelhard's Stoneback says that sales of color dispersions are growing as paint formulators increasingly leave the preparation of dispersions from dry colors to dispersion specialists. The recent incorporation of the Harshaw/Filtrol color business into Engelhard's pigments and additives division puts the company into the dispersants business. Small and medium-size paint producers have incorporated Engelhard's Gallery 1 color pigment in store additive systems for custom coloring of pretinted bases, notes Stoneback.

Hüls America, also, notes that its color dispersion business is growing. "We're superior in making colors and controlling the strength and we are able to guarantee consistency from lot to lot" to the point of providing a certificate of analysis for each batch, says John W. Du, Hüls colorants and coatings research and development manager. Jack Col-

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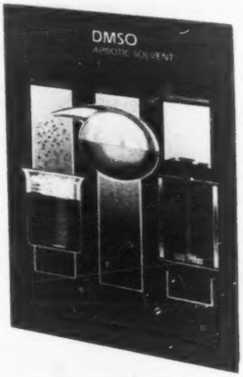

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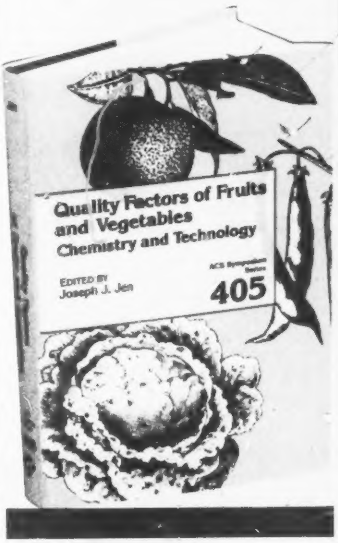
lins, Hüls director of sales, says that the company is working on and can provide new metal driers that will work in higher solids, low-VOC products that allow formulators to comply with California regulations.

In the polymer area, Rohm & Haas' Colau says that use of waterborne acrylic and vinyl acrylics continues to grow and make inroads against high-gloss alkyd solvent-based formulations. Rohm & Haas' HG74 resin is "just gaining acceptance" as a high-gloss acrylic coating for both exterior and interior use, he says. The company's Multilobe acrylic emulsion for exterior applications has been reformulated, he adds, to offer good film build without external thickeners, providing good adhesion to chalky substrates and without the difficulty in mixing some colorants as it had during its first introduction in 1987.

Mobay's Jack J. Bracco, technical marketing manager in the coatings division, says that polyurethane formulations are a natural for growth in the architectural paint market, particularly where high performance is a criterion. Where longevity is a criterion, polyurethanes ought to be used more, he says, though he admits that polyurethane formulations take only about 5% of the high-performance architectural coatings market. Waterborne polyurethane dispersions give off less VOCs in applications on concrete and metal substrates.

Also in the high-performance arena in urethane coating systems, American Cyanamid business manager Robert F. Anderson says that the company is developing uses for its aliphatic isocyanate monomer *m*-tetramethyl xylylene diisocyanate (TMXDI) as part of a high-performance roof coating system that has a foam underlay. The roof system is particularly effective in covering broad expanses, as it has a high degree of elasticity, he says. Anderson also notes that there is increased development emphasis on aqueous systems incorporating TMXDI to form good high-solids high-performance aqueous solutions.

Where high performance in exterior paint formulations is also a criterion, Ciba-Geigy says it has per-



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Joseph J. Jen, *Editor*, University of Georgia
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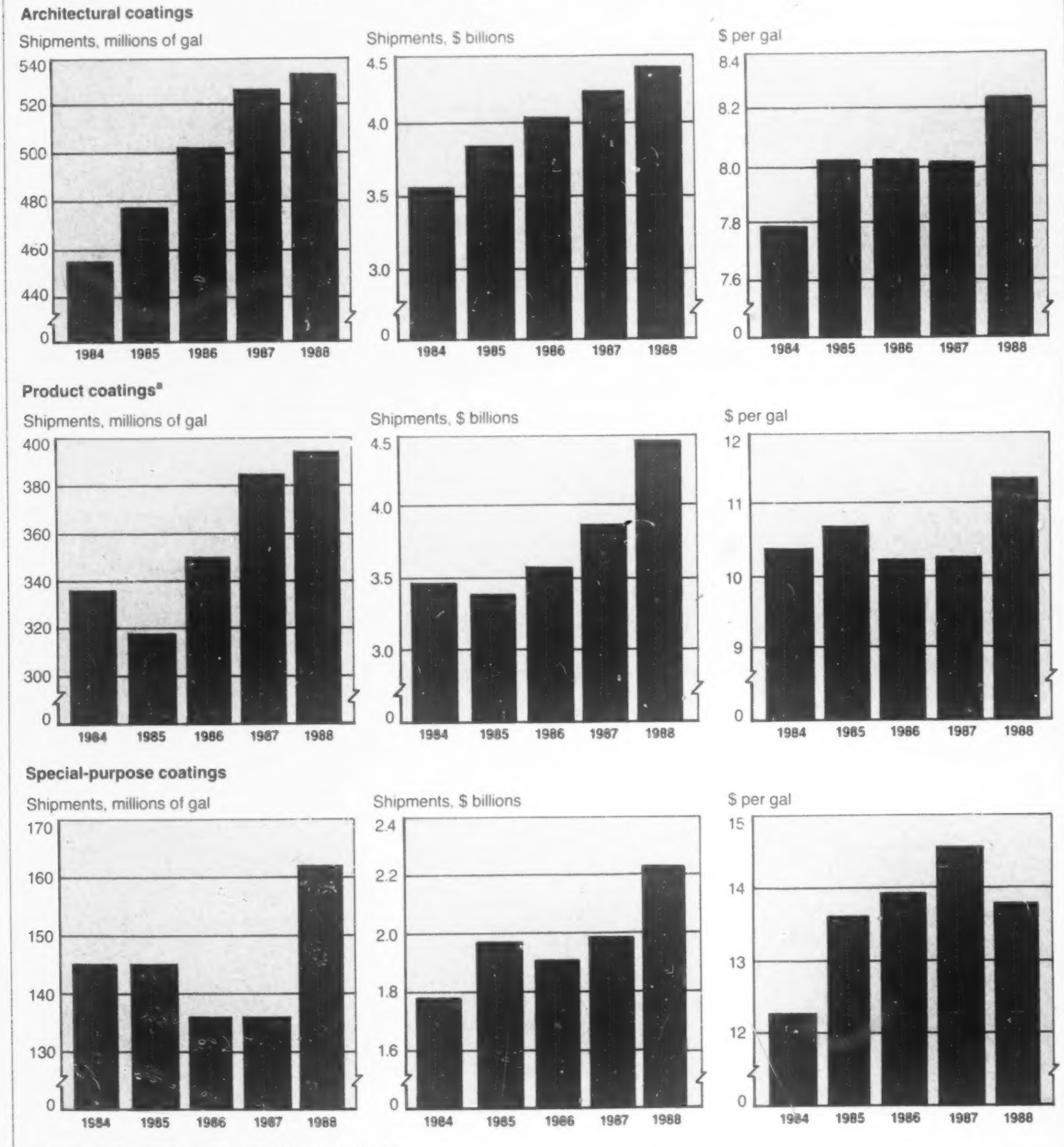

a Original equipment manufacturers. **Source:** Bureau of the Census

fected a new light stabilizer, tentatively referred to as CGL-123, for acrylic melamine, alkyd, and urethane coatings in a host of end-use markets. An adjunct to the current line of Tinuvin UV absorbers based on benzotriazoles and hindered amines, CGL-123 is based on amine ethers and bypasses the chemistry of oxidation in a paint film leading to a longer life coating, says Peter J. Schirmann, marketing and sales manager in the additives division.

The new Ciba-Geigy product likely will be commercially available soon, says Schirmann, though final cost has not been determined. Although production of CGL-123 is more expensive than standard hindered amine chemistry, Schirmann expects that final cost will still prove itself on a cost-performance basis where longer film life is desirable. ☐